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ENGINEERING DESIGN GUIDELINES, DRAWINGS AND SPECIFICATIONS FOR --ETC(U)

DEC 76 F J SCHROEDER, R L KACHINSKI DAAA15-75-C-0120

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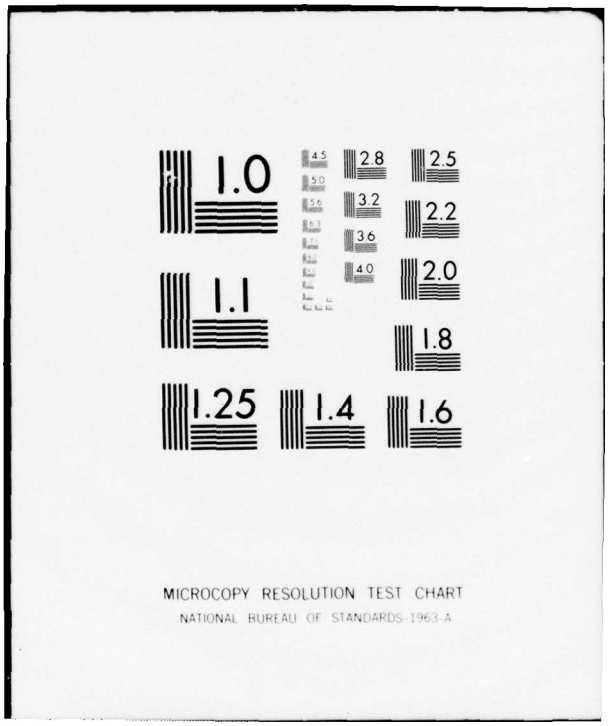
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EDGEWOOD ARSENAL CONTRACTOR REPORT

EM-CR-76097

ENGINEERING DESIGN GUIDELINES, DRAWINGS AND SPECIFICATIONS FOR SUPPORT ENGINEERING OF SUPPRESSIVE SHIELDS

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by

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DDC
MAR 24 1977

DECEMBER 1976

Contract No. DAAA15-75-C-0120 Work Order No. 7

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DEPARTMENT OF THE ARMY
Headquarters, Edgewood Arsenal
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The application of suppressive shielding to ammunition manufacturing and other hazardous operations necessitates provision for access to the operation being protected. Personnel must be able to enter the shield to accomplish routine and emergency maintenance, cleanup and other essential operations. A sufficient opening must also be provided to enable the equipment being protected to be installed or removed in realistically large subassemblies. Openings for conveyors, chutes, motor drives, shafts, etc. must also be

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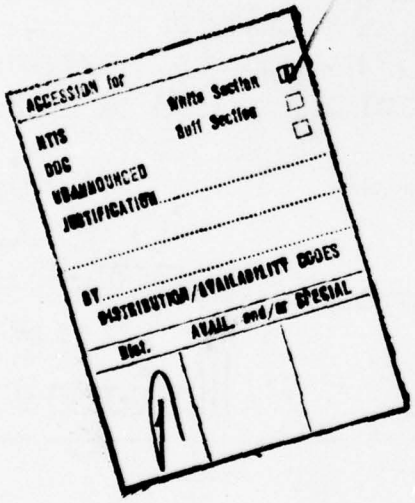
provided and properly configured to preclude fragment penetrations from inside the shield. Provisions must be made for all conceivable utilities and environmental conditioning which may be essential to the operations inside the shield.

These utility penetrations, ventilating and air conditioning ducts, and vacuum lines must not alter the basic mode of structural failure of the suppressive shield and should be small compared to the general size of the shield

Liners, both interior and exterior to the shield, may be required for certain operations, such as those wherein explosive dust is produced, to preclude contamination of the interior of the shield panels.

This report presents the formal documentation of all efforts and the results of a program to acquire and generate the information and data necessary to establish safety approved openings, penetrations, liners, finishes and foundations. Detail design drawings are included as well as substantiating calculations, welding procedures and maintenance procedures for the shields.



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PREFACE

The work represented by this report was performed under task assignment No. 7 to Contract No. DAAA15-75-C-0120 for the Suppressive Shielding Branch, Manufacturing Technology Directorate, Edgewood Arsenal. This report presents the formal documentation of all efforts and results for the time period from November 1975 through December 1976.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software. This report may not be cited for purposes of advertisement.

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ENGINEERING DESIGN GUIDELINES, DRAWINGS AND SPECIFICATIONS FOR SUPPORT ENGINEERING OF SUPPRESSIVE SHIELDS

I. INTRODUCTION

A. Objective

The objective of the task assignment was to acquire and/or generate information and data necessary to establish safety approved openings, penetrations, liners, and other items involved in applying the basic safety approved shield group structures to actual hazardous operations in Army ammunition plants.

B. Background.

The suppressive shielding program was initiated in 1969 to provide protective structures in the form of homogeneously vented enclosures as an alternative to the use of US Army TM 5-1300 walls. Edgewood Arsenal engineers have demonstrated the concept feasibility and have shown that blast overpressure, fireball, and fragmentation hazards from an accidental detonation can be significantly reduced or suppressed. Full scale prototype structures have been developed for applications for chemical agent munition demilitarization, white phosphorus munition processing, explosive ordnance disposal, and munitions production operations.

In 1973, the program was given increased impetus by US Army authorization to provide, within three years, a sound technological base for the concept. At the direction of the Project Manager for Munitions Production Base Modernization and Expansion and with the cognizance of

the Suppressive Shielding Technical Steering Committee, a simultaneous program was initiated to provide proven prototype hardware applicable to hazardous munitions production operations. The Department of Defense Explosives Safety Board has approved five types of suppressive shields for use in US Army ammunition plants.

The five groups of suppressive shields approved cover the range of hazardous operations effects associated with explosive charge weights of up to 37 pounds of TNT equivalent. These are shield groups 3, 4, 5, 6, and the shield for the 81mm mortar round (referred to hereinafter as the "81mm shield"). The group 6 shield is not included in this study as it is not designed to house ammunition manufacturing equipment and does not have the same general operational requirements as the four other groups. Detailed characteristics and performance of these shield groups are shown in Figures 1, 2, 3, and 4 in Section III.

The application of suppressive shielding to ammunition manufacturing and other hazardous operations necessitates provision for access to the operation being protected. Personnel must be able to enter the shield to accomplish routine and emergency maintenance, clean-up, and other essential operations. A sufficient opening must also be provided to enable the equipment being protected to be installed or removed in realistically large subassemblies. Openings for conveyors, chutes, motor drives, shafts, etc., must also be provided and properly configured to preclude fragment penetrations from inside the shield. Provisions must be made for all conceivable utilities and environmental conditioning

which may be essential to the operations inside the shield.

These utility penetrations, ventilating and air conditioning ducts, and vacuum lines must not alter the basic mode of structural failure of the suppressive shield and should be small compared to the general size of the shield.

Liners, both interior and exterior to the shield, may be required for certain operations, such as those wherein explosive dust is produced, to preclude contamination of the interior of the shield panels. In the case of shields such as the group 5 shield, primarily designed for use with propellants or pyrotechnic materials, these liners must not inhibit the venting characteristics of the shield.

II. TECHNICAL APPROACH

The plan for reaching the objectives of this task consisted of five steps which include:

- An on-site survey of representative Army ammunition plants (AAP's) where suppressive shielding might be applied to hazardous operations.
- An evaluation of data gathered during the survey visits to determine requirements for each shield group.
- Development of designs, specifications, and guidelines based on these requirements.
- Preparation of outline test plans for items requiring testing.
- Preparation of a comprehensive final report which will include engineering guidelines to be used for preparing the design details for safety approved personnel openings, utility and product penetrations, and liners.

As the investigations progressed, discussions were held with other interested groups such as the Corps of Engineers, Huntsville, DARCOM safety personnel, and those attending the Suppressive Shielding Technical Steering Committee meeting at Southwest Research Institute in April 1976. As a result, it was determined that safety approval of design guidelines for openings, penetrations, liners, foundations, finishes, and other items necessary to make the shield groups fully operational might be possible without resorting to explosive testing. It was concluded that the results of testing already accomplished to qualify the basic shield group structures and certain openings and penetrations could be used with engineering analysis and rationale to present a sufficient case for

approved designs without having to perform individual tests on each type of opening, penetration, liner, and foundation provided the following criteria are applied:

- Doors for equipment, conveyors, personnel, and penetrations to accommodate utilities in suppressive shields must be designed to develop the full resistance to explosive blast forces of the structure without penetrations, so that the blast resistance of the structure is not impaired locally by any of the penetrations. It is sufficient to demonstrate this analytically by using established techniques for calculating structural response to dynamic loads, provided the penetration is a relatively minor structural feature. If the penetration is likely to change the mode of response of the structure appreciably, or if its dimensions are comparable to the overall shield dimensions, tests would be required to demonstrate the resistance of the modified structure to internal explosive blast.
- Protective covers for the utility penetrations must be designed to furnish the same fragment resistance as the structure. Generally, this will entail providing the same metal thickness in the region of the penetration as in the typical cross section of the shield.

III. FORMULATION OF REQUIREMENTS

A. Summary of Shield Group Characteristics.

The characteristics of each of the basic shield groups are presented in Figures 1, 2, 3, and 4.

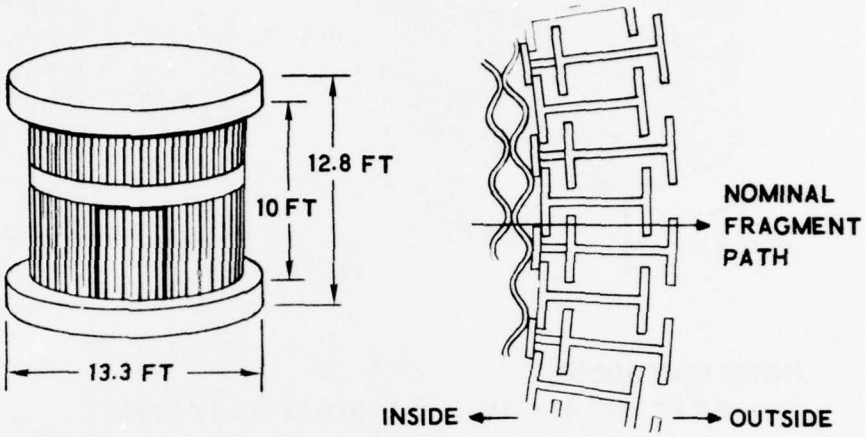
The general constructional configuration of the shield groups 4, 5, and 81 mm are similar and consist of a frame structure which supports flat panels built up from varying arrangements of structural steel angles, Z-sections, and flat steel perforated plates. The basic overall configuration of these three shield group structures is that of a rectangular parallelepiped. The roof of each of these structures is of the same configuration as the particular side panels.

The shield group 3 configuration is different from the others. This structure is cylindrical with structural steel I-beams interlocked in a vertical orientation. The roof and supporting foundation are reinforced concrete bolted to the cylindrical section through cap plates supported by gussets. The space between the innermost flanges of the I-beams is bridged by an element of T-shaped cross section. This member is tack welded to the I-beams at each location. A liner of steel sheet is also provided as a part of the group 3 shield.

B. Summary of Ammunition Plant Surveys.

In order to accomplish the program objectives, it was first necessary to obtain information on the requirements for finishes and maintenance and for the various openings, penetrations, liners, and foundations. A plan was formulated wherein selected Army ammunition plants would be visited by a survey team. The plants were

GROUP #3



INSIDE DIMENSIONS: 11.25 FT DIA, 10 FT HIGH

WEIGHT: 95,540 LBS (INCLUDING FOUNDATION)

TYPE CONSTRUCTION: BUILT-UP STRUCTURE USING I-BEAMS WITH STEEL LINER AND CONCRETE ROOF AND FOUNDATION

CHARGE WEIGHT (50-50 PENTOLITE):

a. DESIGN - 37 LBS

b. PROOF (25% OVERCHARGE) - 45.7 LBS

REFLECTED IMPULSE: (SIDEWALL)

a. CALCULATED DESIGN - 414 PSI-MSEC

b. CALCULATED PROOF - 495 PSI-MSEC

REFLECTED PRESSURE: (SIDEWALL)

a. CALCULATED DESIGN - 2728 PSI

b. CALCULATED PROOF - 3198 PSI

QUASI-STATIC PRESSURE:

a. CALCULATED DESIGN - 145 PSI

b. CALCULATED PROOF - 165 PSI

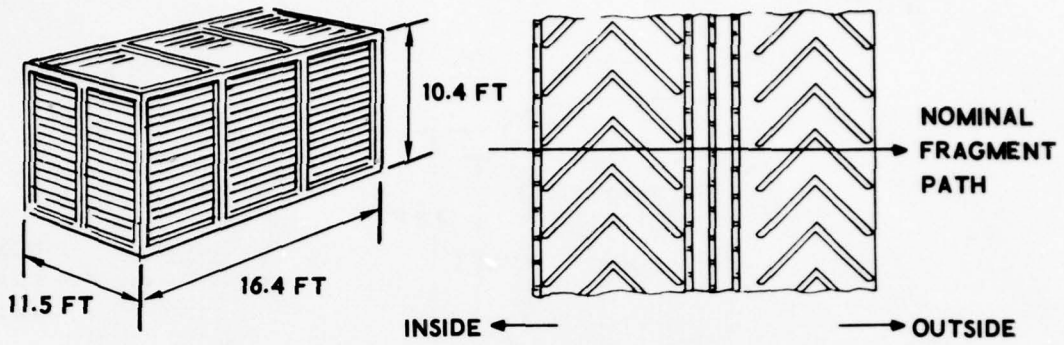
BLOWDOWN TIME (DESIGN): 2 SEC WITH $\alpha_e = 0.4\%$ (TOTAL)

NOMINAL STEEL THICKNESS (FRAGMENT PATH) : 1 IN

STATUS : SAFETY APPROVED

Figure 1 - Shield Group 3 Characteristics

GROUP #4



INSIDE DIMENSIONS:

9.2 FT WIDTH X 13.1 FT LENGTH X 9.3 FT HEIGHT

WEIGHT: 79,159 LBS

TYPE CONSTRUCTION:

I-BEAM FRAME , NESTED ANGLES AND PERFORATED PANELS

CHARGE WEIGHT (PENTOLITE):

a. DESIGN - 9 LBS

b. PROOF (25% OVERCHARGE) - 11.25 LBS

REFLECTED IMPULSE: (SIDEWALL)

a. CALCULATED DESIGN - 162 PSI-MSEC

b. CALCULATED PROOF - 194 PSI-MSEC

REFLECTED PRESSURE: (SIDEWALL)

a. CALCULATED DESIGN - 1387 PSI

b. CALCULATED PROOF - 1464 PSI

QUASI-STATIC PRESSURE:

a. CALCULATED DESIGN - 57 PSI

b. CALCULATED PROOF - 63 PSI

BLOWDOWN TIME (DESIGN): 88 MSEC WITH α_e = 3.09% (TOTAL)

NOMINAL STEEL THICKNESS (FRAGMENT PATH) : 2.17 IN

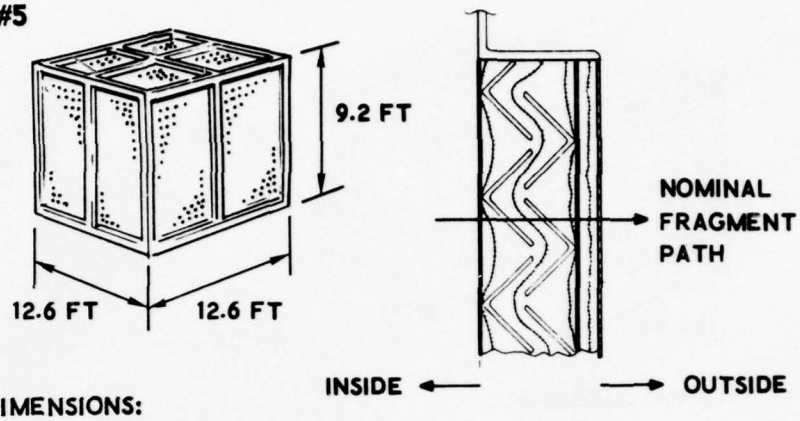
MAXIMUM 2.17 IN.

MINIMUM 1.46 IN.

STATUS : SAFETY APPROVED

Figure 2 - Shield Group 4 Characteristics

GROUP #5



INSIDE DIMENSIONS:

10.4 FT WIDTH X 10.4 FT LENGTH X 8.5 FT HEIGHT

WEIGHT: 16,772 LBS

TYPE CONSTRUCTION:

CHANNEL FRAME, ANGLES, PERFORATED PLATES AND SCREENS

CHARGE WEIGHT (C-4):

a. DESIGN - 1.84 LBS

b. PROOF (25% OVERCHARGE) - 2.44 LBS

REFLECTED IMPULSE:

a. CALCULATED DESIGN - 44 PSI-MSEC

b. CALCULATED PROOF - 55 PSI-MSEC

REFLECTED PRESSURE:

a. CALCULATED DESIGN - 368 PSI

b. CALCULATED PROOF - 493 PSI

QUASI-STATIC PRESSURE:

a. CALCULATED DESIGN - 24 PSI

b. CALCULATED PROOF - 29 PSI

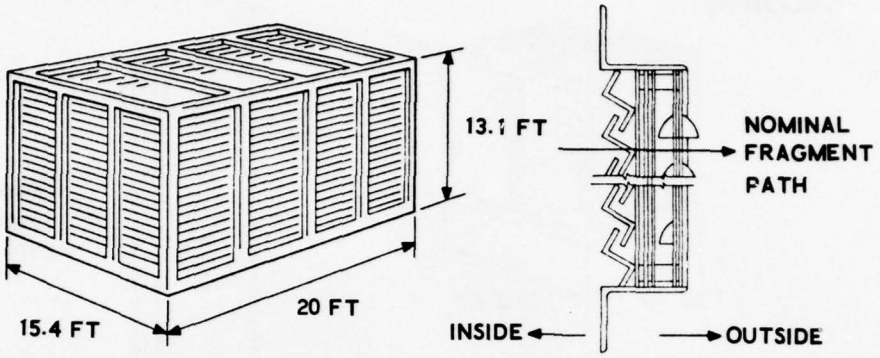
BLOWDOWN TIME (DESIGN): 44MSEC WITH α_e =15.5% (PANELS)

NOMINAL STEEL THICKNESS (FRAGMENT PATH): .427 in. IN.

STATUS : SAFETY APPROVED

Figure 3 - Shield Group 5 Characteristics

GROUP #81 MM



INSIDE DIMENSIONS:

14 FT WIDTH X 18.7 FT LENGTH X 12.4 FT HEIGHT

WEIGHT: 48,750 LBS

TYPE CONSTRUCTION:

BOX BEAM FRAME, Z BARS, PERFORATED PLATES AND LOUVERED PANELS

CHARGE WEIGHT (C-4):

a. DESIGN - 6.72 LBS

b. PROOF (25% OVERCHARGE) - 8.4 LBS

REFLECTED IMPULSE:

a. CALCULATED DESIGN - 97 PSI-MSEC

b. CALCULATED PROOF - 115PSI-MSEC

REFLECTED PRESSURE:

a. CALCULATED DESIGN - 483 PSI

b. CALCULATED PROOF - 610 PSI

QUASI-STATIC PRESSURE:

a. CALCULATED DESIGN - 23 PSI

b. CALCULATED PROOF - 28 PSI

BLOWDOWN TIME (DESIGN): 82 MSEC WITH α_e = 4.3% (TOTAL)

NOMINAL STEEL THICKNESS (FRAGMENT PATH): 1.23 IN.

STATUS : SAFETY APPROVED FOR TWO 81 MM ROUNDS.
SAFETY APPROVAL HAS BEEN REQUESTED FOR
6.72 LB. OF C-4 OR EQUIVALENT.

Figure 4 - Shield Group 81MM Characteristics

selected to provide a cross section of hazardous operations to which suppressive structures could be applied. The plants selected for the survey were:

Lake City AAP, Independence, Missouri

Kansas AAP, Parsons, Kansas

Milan AAP, Milan, Tennessee

Iowa AAP, Burlington, Iowa

Indiana AAP, Charlestown, Indiana

Table 1 presents a summary of the potential applications for suppressive shielding at these AAP's and the corresponding shield groups to be considered.

In preparation for these on-site surveys, a letter was sent to the Commanding Officer of each of the AAP's requesting assistance in obtaining the required information and data. Also included was a questionnaire pertaining to the information desired. A copy of this letter and attendant list of questions is presented in Appendix A.

The survey of AAP's provided some of the data for establishing the criteria for finishes and maintenance, and for the various penetrations, openings, liners, and foundations necessary to enable the basic shield group structures to be made operational. Table 2 summarizes the information gathered through these survey visits as well as from other sources, such as the Corps of Engineers, Huntsville.

TABLE 1. Plant Survey Summary

AAP visited	PBM&E Projects surveyed	Application of safety approved S/S.	Other operations surveyed	Potential S/S applications
Lake City	o 3501 - 20/25/30 mm SCAMP production	o S/G 3 or 81 mm	o Tracer charging o 5.56/7.62 mm blank cartridge loading o Primer mfg. o Propellant storage	S/G 3 S/G 4 or 81 mm S/G 5 S/G 5
Iowa	o 2676 - Detonator facility front line o 2677 - 155 mm M549 M708 & 8" XM650 LAP	o S/G 6 o Quantities appear to be too large for currently safety approved shields	o XM718 LAP line (Shaped charge tank mine) o Melt-pour system o Automatic HE screening & weighing	o S/G 3 or 4 o S/G 1 o S/G 3
Indiana	o 2500 - 105 mm M67 propellant charge load & assembly o 2610 - 155 mm & 8" Propellant charge bag loading facility	o Quantities appear to be too large for currently safety approved shields o Same as Proj.#2500	o Black Powder plant - cake processing	o S/G 3 or 4 Around presses
Kansas	o 2702 - Detonator facility front line	o S/G 6	o 81 mm Ingersoll-Rand Automated LAP line o 105 mm (1000) line o CBU (1100) line	o 81 mm S/S around fuze cavity drilling & facing o S/G 3 or 4 o S/G 3 or 4
Milan	o 2709 - 60/81 mm MELT pour system	o 81 MM	o Minute-melter o 81 mm Ingersoll-Rand automated LAP line	o S/G 2 o 81 mm S/S around fuze cavity drilling and facing

TABLE 2 - REQUIREMENTS MATRIX

TYPE	SHIELD TYPE	TYPICAL APPLICATION	REQUIREMENTS AND SIZING	REMARKS
A. Utilities				
Electricity	2	Minute Melter	Required, Sizing Undefined	
	3	Igniter Mix Press, Exp. Mat Screening	Required, Sizing Undefined	
	4	105 mm LAP Fuze	Required, Sizing Undefined	
	5	20 mm HEI	125 KVA, 2" - 3" Line	LCAAP Application
	81 mm	Cavity Facing Operation	440 - 480V 3Ø, or 2 inch dice 120 Volt, single Ø ~ 1/2 inch dia.	Dependent upon amperage
Water - General Use	2	Minute Melter	For Washdown, 1/2" diameter hose, 8GPM Nominal Flow	
	3	IgniterMix Press, Exp. Mat Screening	For Washdown, 1/2" diameter hose, 8GPM Nominal Flow	
	4	105mm LAP Fuze	None Required	
	5	20 mm HEI	None Required	
	81 mm	Cavity Facing Operation	For Washdown, 1/2" diameter industrial hose, 8 GPM Nominal Flow	
Deluge	2	Minute Melter	450 - 500 GPM, 80 psig. 4 - 5 in. line	
	3	Igniter Mix Press, Exp. Mat Screening	2 - 2 1/2" lines (80-90 GPM) 80 psig	
	4	105 mm LAP Fuze	2 - 2 1/2" lines (80-90 GPM) 80 psig	
	5	20 mm HEI	2 - 2 1/2" lines (80-90 GPM) 80 psig	
	81 mm	Cavity Facing Operation	2 - 2 1/2" lines (80-90 GMP) 80 psig	

TABLE 2 - CONTINUED

TYPE	SHIELD TYPE	TYPICAL APPLICATION	REQUIREMENTS AND SIZING	REMARKS
Vacuum Systems	2	Minute Melter	None for Assembly, Cleanup Required	
	3	Igniter Mix Press Exp. Mat Screening	Undefined	
	4	105 mm LAP Fuze	None for Assembly, Cleanup Vacuum Required	
	5	20 mm HEI	Required, Requirements not Defined	
	81 mm	Cavity Facing Operation	300-400 CFM/Cubicle - 6" Hg Vacuum, 2" Diameter	System also required for cleanup can be vacuum cleaner style
Compressed Air	2	Minute Melter	100 psig dry supply, Flow undefined	
	3	Igniter Mix Press Exp. Mat Screening	Required, Sizing Undefined	
	4	105 mm LAP Fuze	100 psig dry supply, flow undefined	
	5	20 mm HEI	Undetermined	
	81 mm	Cavity Facing Operation	100 psig, 25 - 30 CFM, Dry	
B. Environmental Conditioning				
Heating	2	Minute Melter	Required, Temp undefined	
	3	Igniter Mix Press Exp. Mat Screening	Required, Temp ~70 - 75°F	
	4	105 mm LAP Fuze	Undefined	
	5	20 mm HEI	System must maintain 70 - 75°F	
	81 mm	Cavity Facing Operation	None Required	

TABLE 2 - CONTINUED

TYPE	SHIELD TYPE	TYPICAL APPLICATION	REQUIREMENTS AND SIZING	REMARKS
Air Conditioning	2	Minute Melter	Undefined, Probably Required	
	3	Igniter Mix Press Exp. Mat Screening	Required, 65 ± 5°F	
	4	105 mm LAP Fuze	Undefined	
	5	20 mm HEI	None Required	
	81 mm	Cavity Facing Operation	None Required	
Dehumidification	2	Minute Melter	Undefined, Probably Required	
	3	Igniter Mix Press Exp. Mat Screening	Required, Undefined	
	4	105 mm LAP Fuze	Undefined	
	5	20 mm HEI	45 - 55 % RH	
	81 mm	Cavity Facing Operation	None Required	
Ventilation	2	Minute Melter	Undefined, Probably Required	
	3	Igniter Mix Press Exp. Mat Screening	Required, Undefined	
	4	105 mm LAP Fuze	Undefined	
	5	20 mm HEI	Undetermined	
	81 mm	Cavity Facing Operation	None Required	

TABLE 2 - CONTINUED

TYPE	SHIELD TYPE	TYPICAL APPLICATION	REQUIREMENTS AND SIZING	REMARKS
C. Openings				
Personnel	2	Minute Melter	Maintenance Personnel	
	3	Igniter Mix Press Exp. Mat Screening	Maintenance Personnel	
	4	105 mm LAP Fuze	Maintenance Personnel-Similar to 81 mm	
	5	20 mm HEI	Maintenance Personnel-Similar to 81 mm	
	81 mm	Cavity Facing	Sliding Door - 11 x 4 feet suspended by Monorail	Ref EM-CR-76018
Handling Equipment Installation and Removal Oriented	2	Minute Melter	Undefined	
	3	Igniter Mix Press Exp. Mat Screening	Undefined, ~2.5' x 5' (From Drawing)	
	4	105 mm LAP Fuze	Undefined	
	5	20 mm HEI	None Required	
	81 mm	Cavity Facing Operation	Required, ~4' x 6'	
Handling Equipment Munitions Movement	2	Minute Melter	Product Door, Component Transfer System	Dependent Upon Design
	3	Igniter Mix Press Exp. Mat Screening	Product Door	
	4	105 mm LAP Fuze	Product Door	
	5	20 mm HEI	Yes, Powder Input and Component Transfer System	Dependent Upon Design
	81 mm	Cavity Facing Operation	Rotating Product Door - 11" High by 14" in Diameter	Ref EM-CR-76018

TABLE 2 - CONTINUED

TYPE	SHIELD TYPE	TYPICAL APPLICATION	REQUIREMENTS AND SIZING	REMARKS
D. Protective Liners				
Internal	2	Minute Melter	Liner Required	
	3	Igniter Mix Press Exp. Mat Screening	Two Liners 12 gauge (.081 " each)	
	4	105 mm LAP Fuze	Liner Required	
	5	20 mm HEI	Liner Required	
	81 mm	Cavity Facing Operation	Liner Required to prevent dust from entering shield configuration	
External	2	Minute Melter	Liner Required	
	3	Igniter Mix Press Exp. Mat Screening	None Required	
	4	105 mm LAP Fuze	None Required	
	5	20 mm HEI	None Required	
	81 mm	Cavity Facing Operation	Liner Required	
E. Other				
Lighting	2	Minute Melter	Fluorescent Type Fixtures, Explosive Proof	
	3	Igniter Mix Press Exp. Mat Screening	Fluorescent Type Fixtures, Explosive Proof	
	4	105 mm LAP Fuze	Fluorescent Type Fixtures, Explosive Proof	
	5	20 mm HEI	Fluorescent Type Fixtures, Explosive Proof	
	81 mm	Cavity Facing Operation	Fluorescent Type Fixtures, Explosive Proof, 277 Volt	

IV. DISCUSSION OF UTILITY PENETRATIONS.

The utility services which must be provided to the operations inside the suppressive shields considered in this investigation consisted of electricity, water both for general use and deluge systems, and compressed air. For ease of installation, the utility penetrations in the groups 4, 5, and 81mm shields are located directly adjacent to a column or beam member at the floor or ceiling of the structure. For the group 3 shield, which does not have beam or column members like the others, the penetration is located above the floor gussets and is supported by them.

The individual utility lines should be arranged with the lowest being deluge water, next highest the general water service, then compressed air and finally the electrical line in the topmost position. This is recommended to preclude water, leaking from loose or improperly installed connections, from contacting the electrical line and causing a short circuit. An artist's concept of a typical utility penetration is shown in Figure 5 and locations of typical penetrations are shown in Figures 6 and 7.

Utility lines passing through suppressive shield walls are vulnerable to both blast and fragment hazards. The blast could push unprotected utility penetrations through the walls of the shield and create secondary fragments, or fragments from the exploding operation could penetrate the thin walls of an unprotected utility pipe.

A protective box was designed to eliminate the challenge of blast and fragments to the utility penetrations. This protective box surrounds the right angle bend of the utilities as they pass through the shield wall. The box rests on the inside of the shield wall and is tack welded in place.

In the recommended design, the actual penetrations through the shield wall are limited to those required for the utilities, i.e., pipes of 1/2 inch to

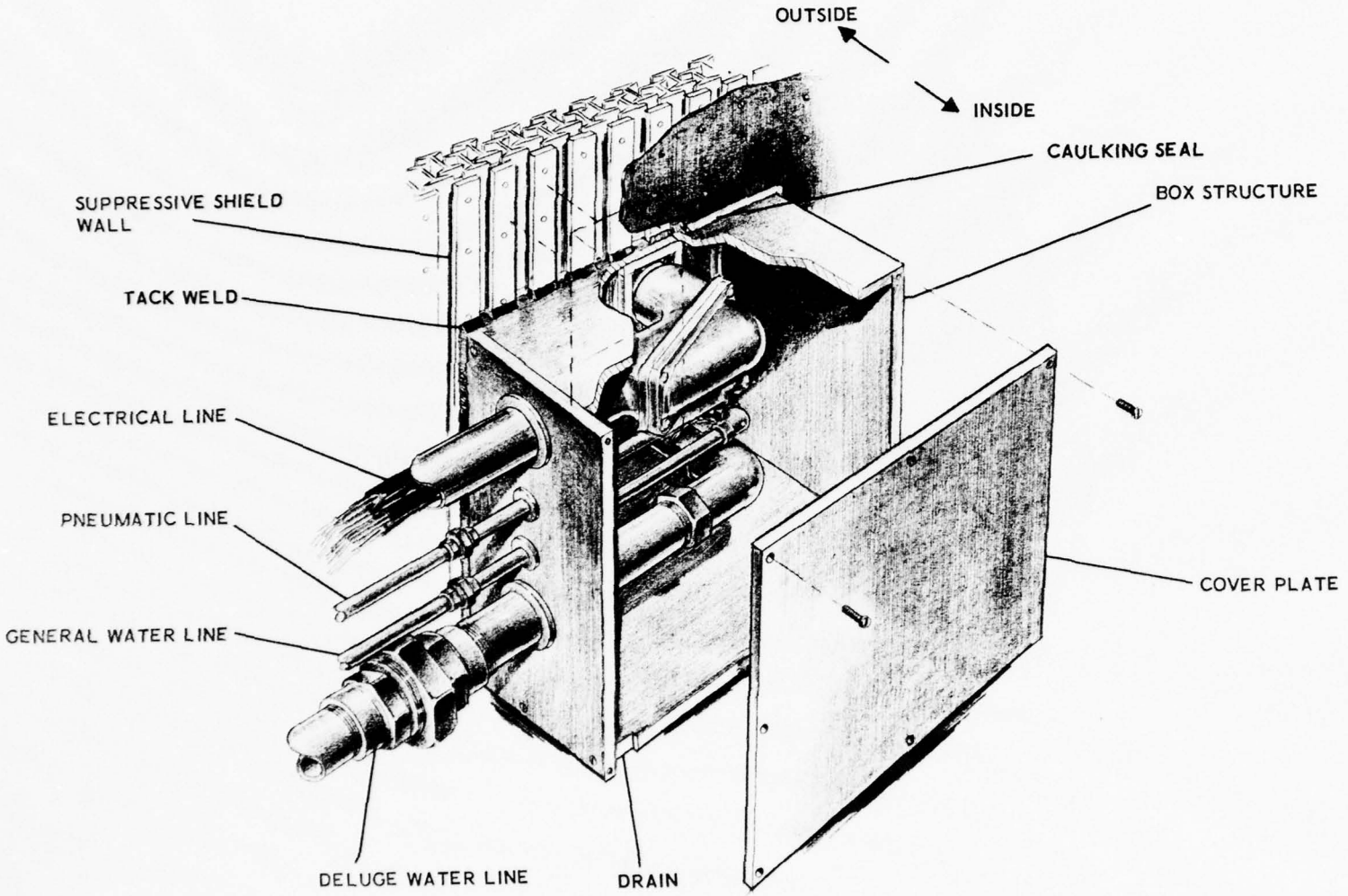


Figure 5 - Typical Utility Penetration

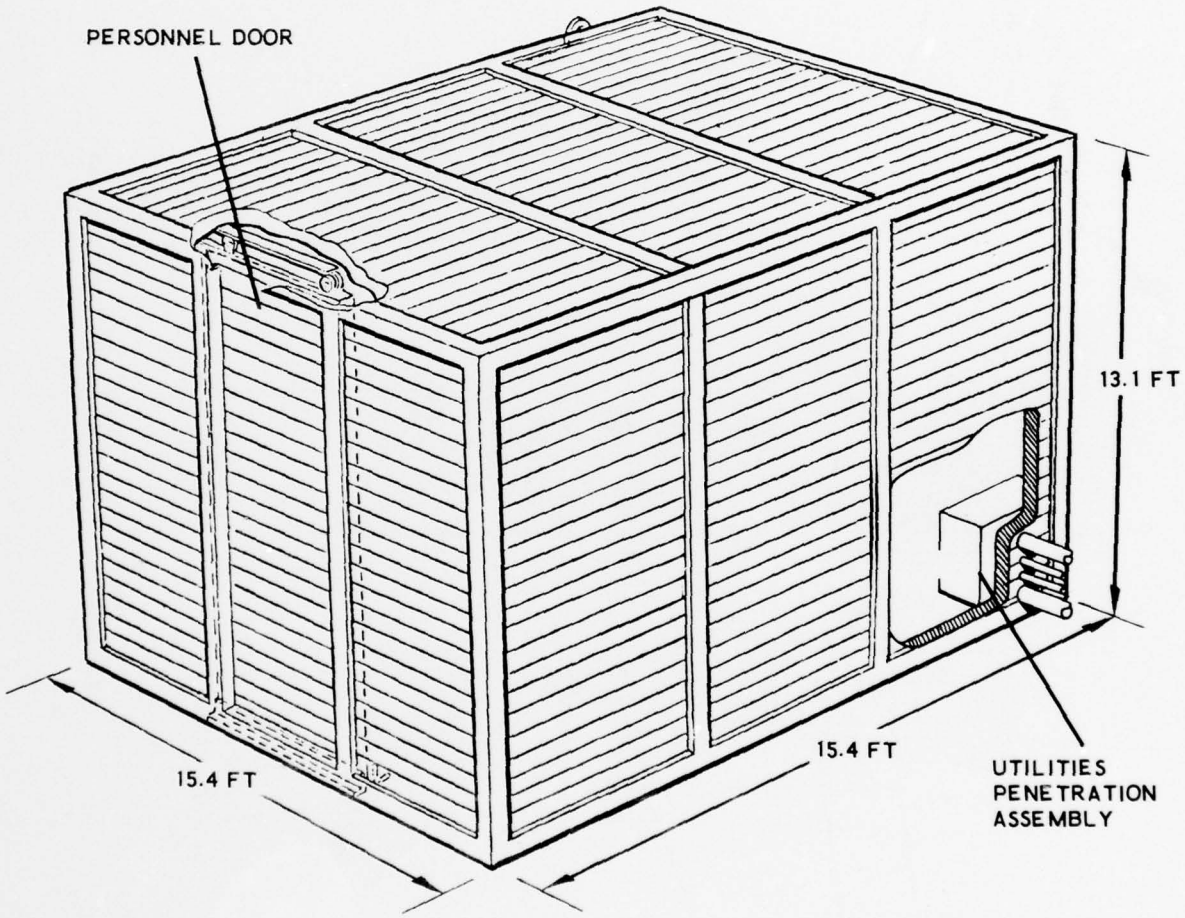


Figure 6 - Typical Location of Utility Penetration in Shield Groups 4, 5 and 81mm

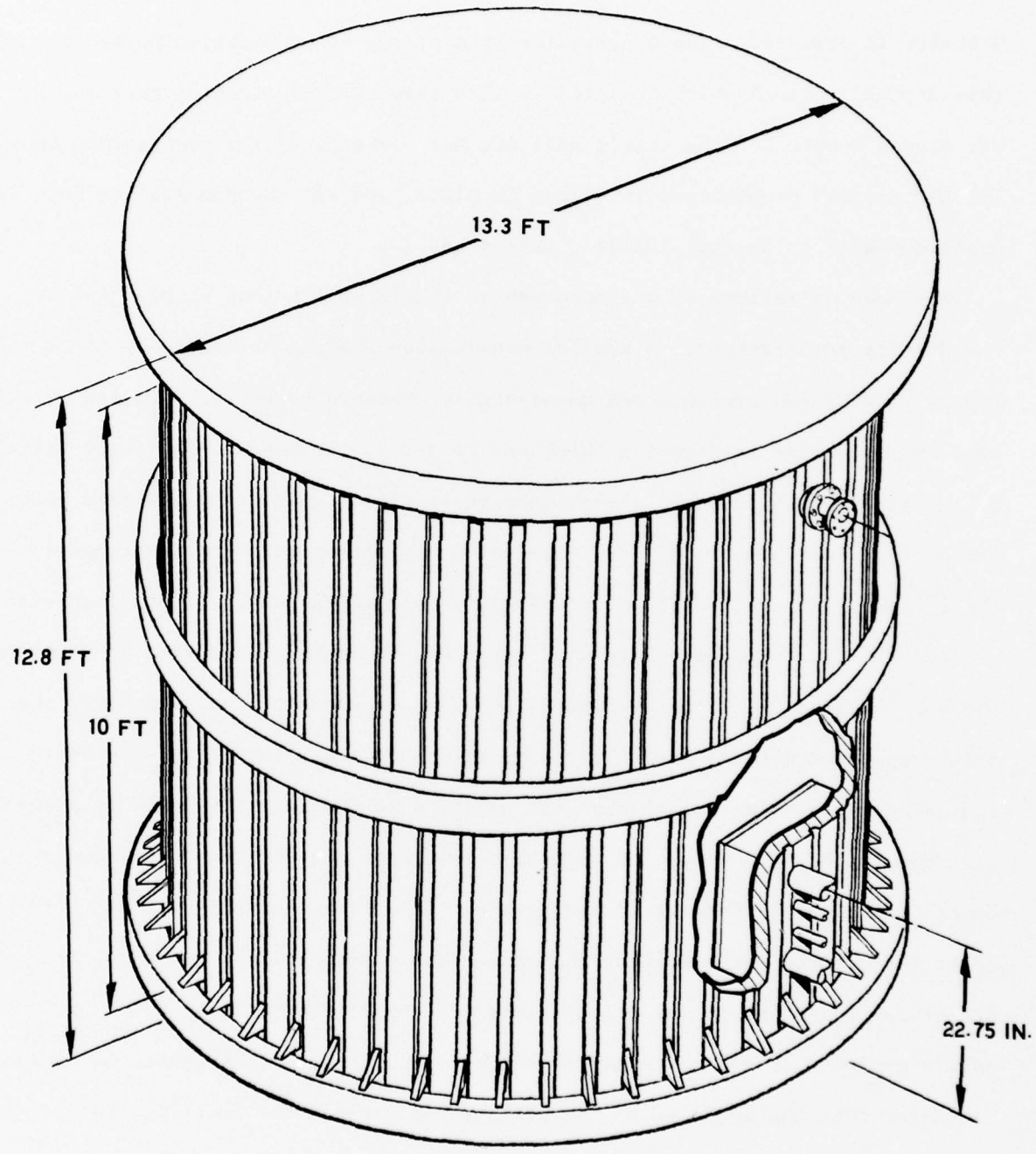


Figure 7 - Typical Location of Utility Penetrations
in Shield Group 3

3 inches in diameter. The penetration is a sleeve or box section welded to the shield panel through which the utility line passes. This insures that the structural members of the shield wall are not weakened by the penetration because (1) the utility penetration is welded in place, and (2) the penetration hole is small compared to the total shield wall area.

The mode of failure of the suppressive shield will not be changed due to the utility penetrations. A similar penetration system was tested on all shield groups. Reflected pressure and quasi-static pressure gages were mounted in shield walls using a pipe penetration which was welded to the panel. The inner diameter of the pipe was threaded to accommodate the pressure gages. No problems were encountered for these 1-3/4 inch diameter penetrations during tests conducted in the 1/4 and 1/16 scale group 1 test fixtures and the group 3, 4, and 5 shields.

The utility box cover plate was designed to stop fragments from penetrating the box. The nominal steel thickness shown in figures 1, 2, 3, and 4 for the safety approved shields was selected as the cover plate thickness. Analysis indicated that the material thickness required to stop the fragments is greater than the thickness required to withstand the blast pressure loading; however, calculations were performed to assure that the utility box side plates would not shear through the panel wall or that the added mass would not adversely affect the structural response. These calculations are summarized in Table 3 for each safety approved shield and a sample calculation is shown in Appendix B. Table 3 indicates that the addition of the utility box reduces the ductility ratio, μ. This is caused by the added mass increasing the natural period which reduces the structural deflection and the ductility ratio.

It is concluded that the addition of the utility box to the interior of the shield wall will not adversely affect the basic response of the structural elements.

TABLE 3 SHEAR AND STRUCTURAL RESPONSE DATA

SHIELD GROUPS	SHEAR SAFETY MARGIN, M_s **	STRUCTURAL DUCTILITY RATIO	
		ORIGINAL μ	μ WITH PROTECTIVE BOX
3	9.1	24.2	8.8
4	6.6	3.4	3.1
5	31.3	6.0	4.0
81MM	12.6	40*	35*

*Based upon 5.25 lbs. of pentolite

** $M_s = \frac{\text{Shear Strength of Material}}{\text{Dynamic Shear Stress } (S_w)} - 1$ based on S_w which is the shear stress of the protective box through the shield wall

V. DISCUSSION OF VACUUM LINE PENETRATIONS

Vacuum line penetrations are required for those operations where explosive chips and dust are generated, for example, the fuze cavity drill and facing operation for the 81mm mortar projectile.

Depending upon the details of the operation requiring a vacuum line, the location of the penetration could be either in the side walls or the ceiling of the shield. The vacuum line penetration is designed to be located in the corner of the shield groups 4, 5, and 81mm adjacent to a beam and column, two beams, or a column and the base of the shield. For the group 3 shield, the vacuum line penetration is designed to pass through the wall at any location on the centerline of an inner vertical I-beam. The roof on the group 3 shield is reinforced concrete and no penetrations have been designed to pass through this structural element.

A design study was conducted (Reference 1) to determine the most desirable system for removal of explosive chips and dust. The vacuum system was selected. Details of the penetration of the vacuum line are illustrated in Figure 8 and typical vacuum line penetrations are shown in Figures 9 and 10. The external cylinder which houses the vacuum line is designed to prevent hazardous fragments from penetrating the cylinder wall. The cylinder is flanged on both sides of the shield panel to allow attachment of elbows as shown. This further prevents any fragments from penetrating the vacuum line and possibly exiting the shield.

Design analysis of the vacuum line for an accidental detonation inside the vacuum line is presented in Reference 1 and is not included herein. The reader should refer to that report for detailed discussion and analysis

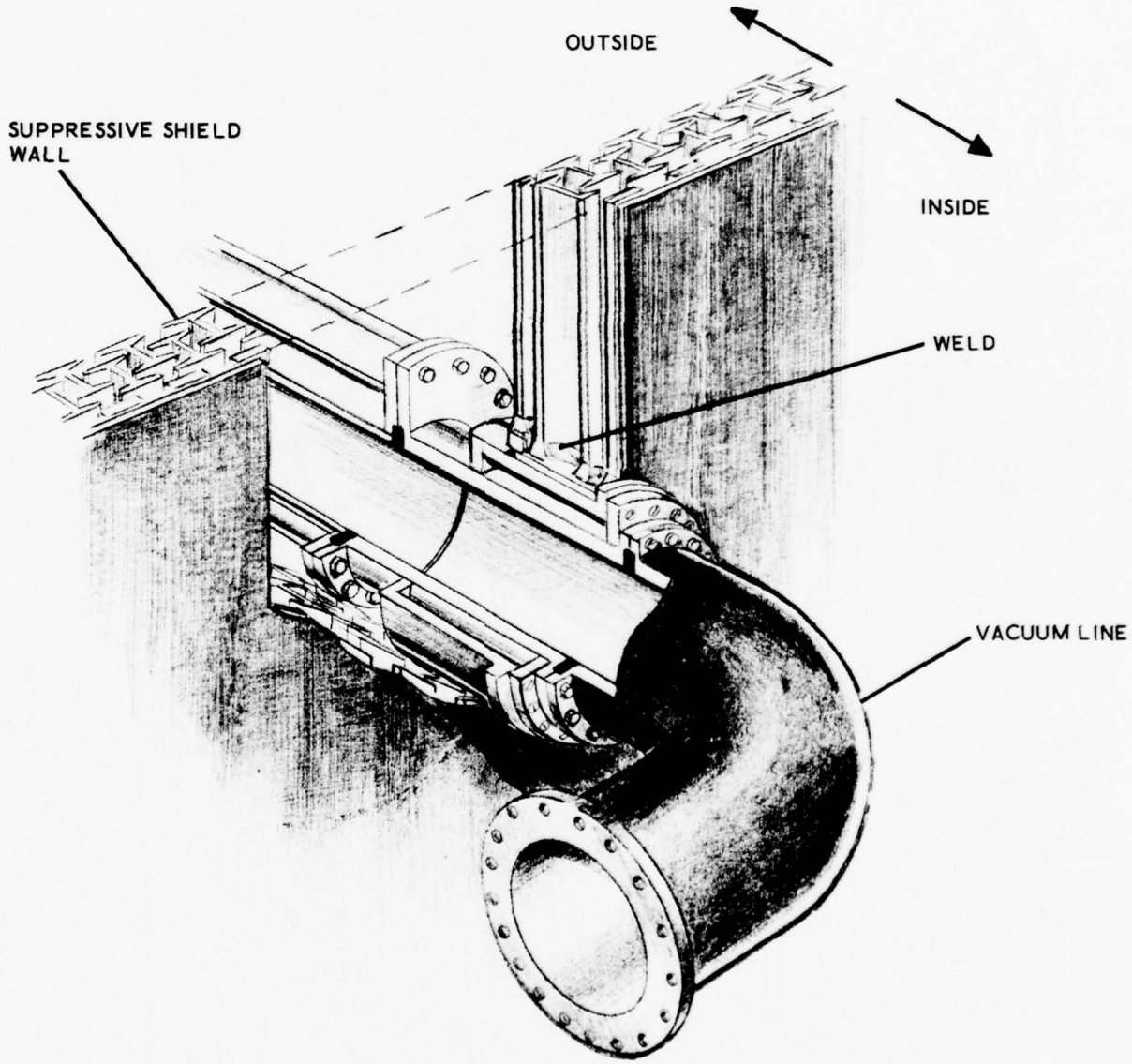


Figure 8 - Vacuum Line Penetration

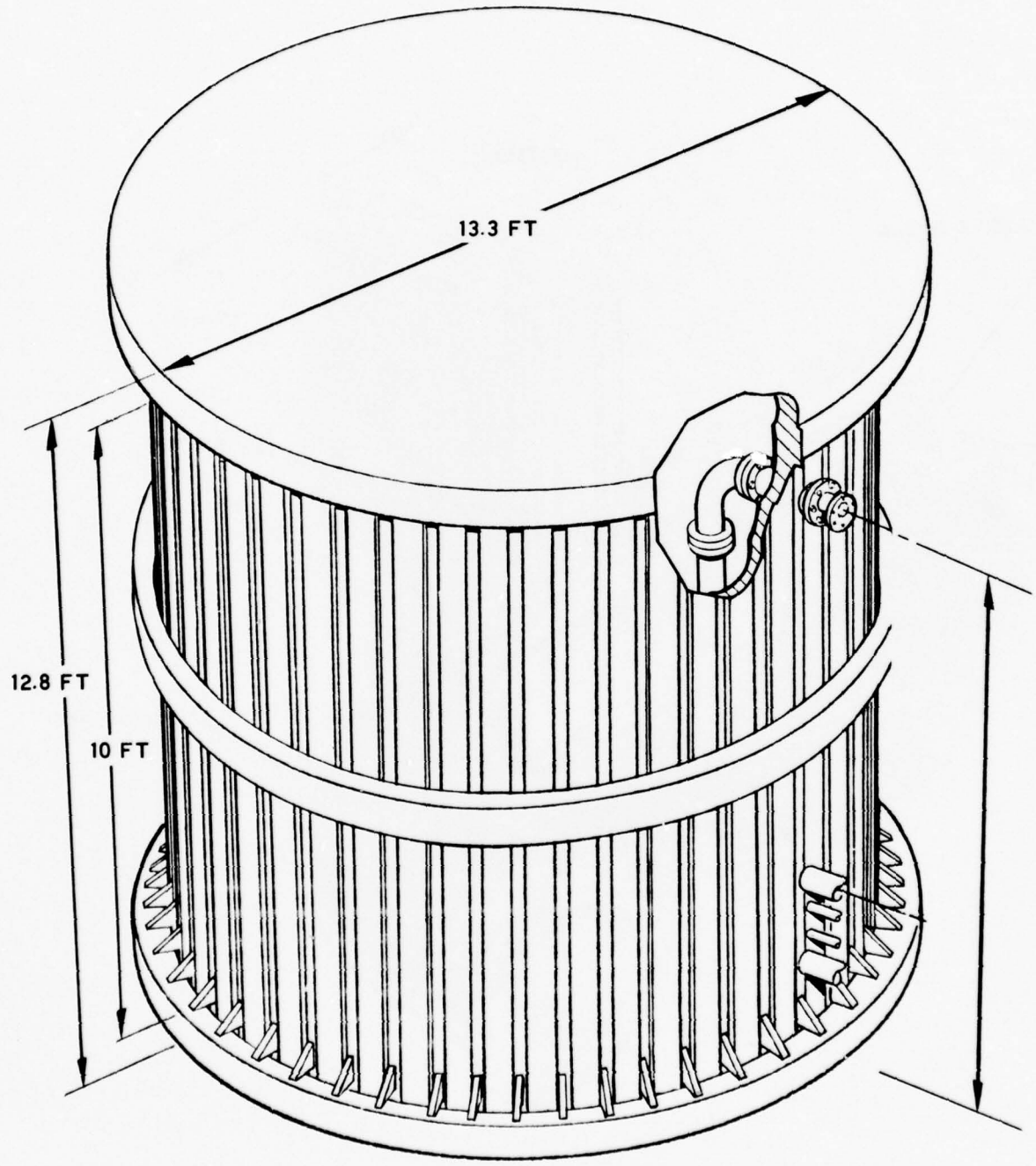


Figure 9 - Typical Location of Vacuum Line Penetration in Shield Group 3

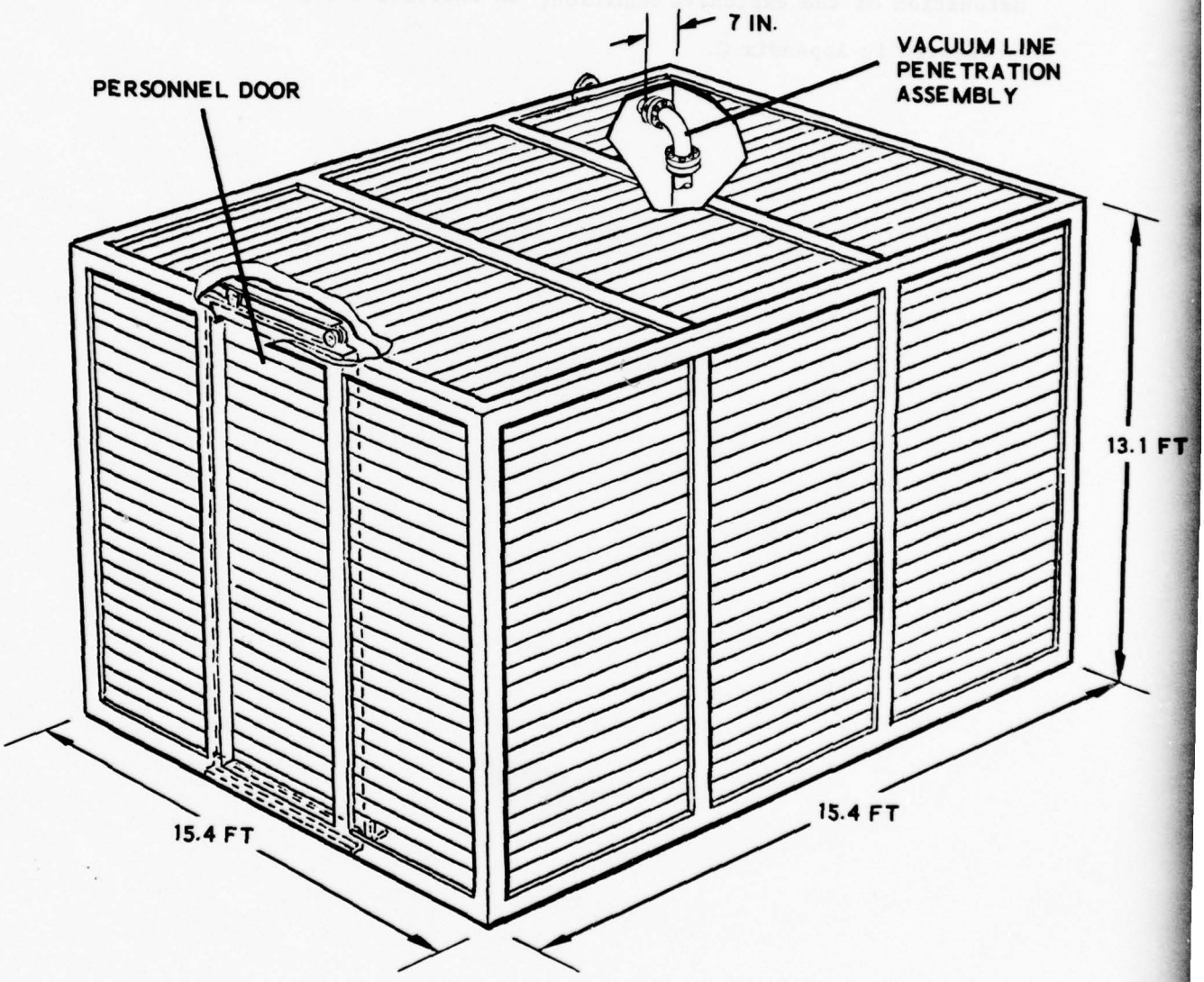


Figure 10 - Typical Location of Vacuum Line Penetration
in Shield Groups 4, 5 and 81mm

of the blast loading and response.

To assure that the vacuum line penetration through the shield panel will not fail due to the internal blast loading resulting from the detonation of the explosive munition, an analysis was performed and is presented in Appendix C.

VI. LINERS.

A. Introduction. The vented or porous nature of the suppressive shield walls creates a potential for explosive and/or flammable dust to filter into and subsequently accumulate within the wall interior. The dust could come from an operation being performed inside the shield or from an exterior source. A means for attaching and sealing both the interior and exterior of the vented panels must be provided. The concept selected to prevent the accumulation of dust in the shield wall is a liner which covers the inner and outer surfaces of the vented panels. Special attention should be given to the joints of the inner and outer liners to assure that the joints will not provide a route for explosive dust entry into the shield wall structure and that the joints themselves will not create an additional location for the accumulation of explosive dusts.

The addition of liners to a suppressive shield could have an adverse effect on the performance of shields of certain groups if the nature of the hazardous material being shielded is not considered. When shielding hazardous operations which involve pyrotechnic materials or propellants, the ventilating properties of the shield must be designed to minimize the long duration pressure load on the structure. The liner for such applications must break or burn away so that ventilating properties are retained. For explosive materials the ventilation requirements are different. If the structure is designed to withstand the combined impulsive and quasi-static pressure loads, fragment impact, and thermal effects, a continuous metal liner which remains in place during the incident (e.g.,

the metal liner for the group 3 shield) is acceptable. Such continuous metal liners must not seal the shield sufficiently to prevent the products of combustion from venting such that the shield becomes in effect a pressure vessel. Some shields for use with explosives, such as the 81mm shield, are not designed to withstand the loads they would experience with a continuous metal liner. Liners for these shields must be designed so that the initial blast overpressure blows out the liner to provide the venting properties designed into the shield. In all designs with liners which break away, care must be taken that hazardous secondary fragments are not produced outside the shield by pieces of the liner.

Some preliminary tests (Ref. 2) with plastic sheet liners, i.e., polyethylene and mylar sheeting, were conducted in the 81mm suppressive shield at NASA National Space Technology Laboratories (NASA NSTL) by the Edgewood Arsenal Resident Laboratory to determine the effect of liners on structural loading and blast attenuation. Blast pressure measurements outside the vented walls compared to those outside the lined walls showed no measurable difference. This indicated that the thin (4-6 mil) plastic liner did not attenuate the explosive blast effects to any measurable degree. Internal pressures and hence, loading of the frame and panel structure, were also not significantly affected by the use of the liners.

Tests have also been conducted in the group 3 and 5 shields using metal liners covering the interior surfaces of these shields. Strain gauge data from high explosive tests in the group 3 shield indicated no significant increase in the loads imposed on the structural members due to the blast containment by the metal liners (Reference 3). Similar tests in a group 5

shield with metal liners indicated no apparent visual degradation of the structure when compared to tests with identical charge weights in the group 5 shield without metal liners.

These tests with the thin metal and plastic interior liners have thus demonstrated that:

(1) Explosive materials can be confined in a suppressive shield with a rigid liner that does not allow venting of the blast pressure if the structure is designed to take the loads.

(2) A frangible plastic liner can be used on a shield containing explosive materials without affecting the venting characteristics.

(3) For deflagrating materials (pyrotechnics and propellants), the venting is essential to prevent shield damage.

B. Liners for Explosive Materials.

Thin steel sheet internal liners have been tested in the group 3 and 5 shields. The group 3 shield liners investigated were:

(1) 24-gage (.024inch) corrugated galvanized steel.

(2) Two 22-gage (.060 inch) corrugated galvanized steel.

The 24-gage liner sustained considerable failure in the 45.7-pound explosive proof tests. The liner sheared along the edges of the blocking strips (where the liner was unsupported) indicating insufficient strength. In the subsequent proof tests in the group 3 shield using the two 22-gage liners, the shearing did not occur though the liner was flattened and some bulging resulted. The two layers of material had their lap joints staggered so

that they were 13 inches apart and were attached by pop rivets and 10 penny nails at the top and bottom edges of the liners.

The group 5 shield liner was flat galvanized steel sheet, 24-gage. A single sheet was used to cover each panel and was attached using sheet metal screws. This liner was successfully proof tested with 2.44 pounds of C-4 explosive. Pressure measurements indicated no difference between the group 5 shield proof tests with or without liners. Therefore, steel liners can be used on the group 5 shield when this shield is applied to explosive operations.

Steel liners have not been tested in the 81mm shield or the group 4 shield and are not proposed for use on these shields. Insufficient data is available to allow application of the liners used in the group 3 and 5 shields to the explosive operations of group 4 and the 81mm shield.

For final application of liners to the group 3 and 5 shields, a soft gasket material or caulking compound is recommended to seal the liner-panel interface and to prevent accumulations of explosive dust at inaccessible locations. Typical installation details are shown in Figure 11.

C. Liners for Deflagrating Materials. Tests conducted in the group 5 shield with internally installed thin metal liners and 50-pound charge of deflagrating illuminant composition (55% $NaNO_3$-45% Mg granulated) resulted in significant permanent deformation of the structural members. Roof members were bent approximately 2 inches from normal and the wall columns approximately 1 inch. Previous tests in this shield without liners and illuminant composition charges of from 10-50 pounds caused no measurable

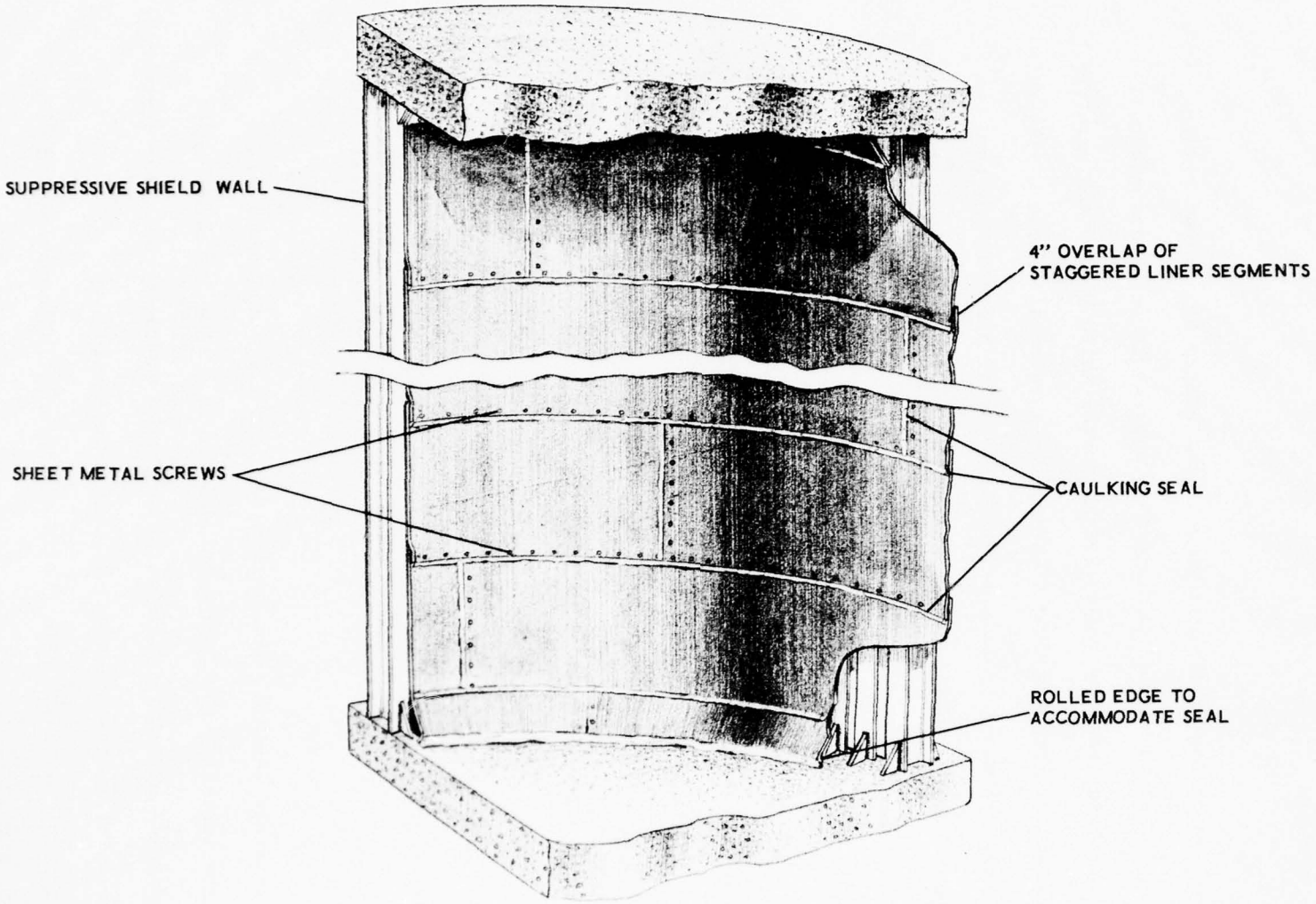


Figure 11 - Typical Installation of Thin Metal Liners

distortion of the structural members (Reference 4). These results indicate that the group 5 shield will require internal and external liners fabricated from lightweight material which will disintegrate, decompose, or fracture when a deflagrating material reacts in the shield. This will allow the rapidly expanding gases to bleed off as they are produced by the reaction, thus preventing an excessive pressure buildup in the structure.

A number of plastic film materials were investigated as possible candidates for suppressive shields requiring frangible internal liners. The material tentatively selected was the 3-M Company's Velostat plastic film. This material exhibits the following properties:

- conductive
- abrasive/tear resistant
- disintegrates rapidly under flame
- workable

It can be purchased with an adhesive applied to one side to allow easy attachment to the panel surface. Attachment would be accomplished as shown on Figure 12.

The liner material for external application requires the same characteristics as the internal liner material plus the additional requirements of being incapable of producing lethal or damaging fragments. The Velostat material meets all these requirements.

Care must be taken with the installation of adhesive-backed plastic liners to prepare the shield surface so a good bond is achieved and to

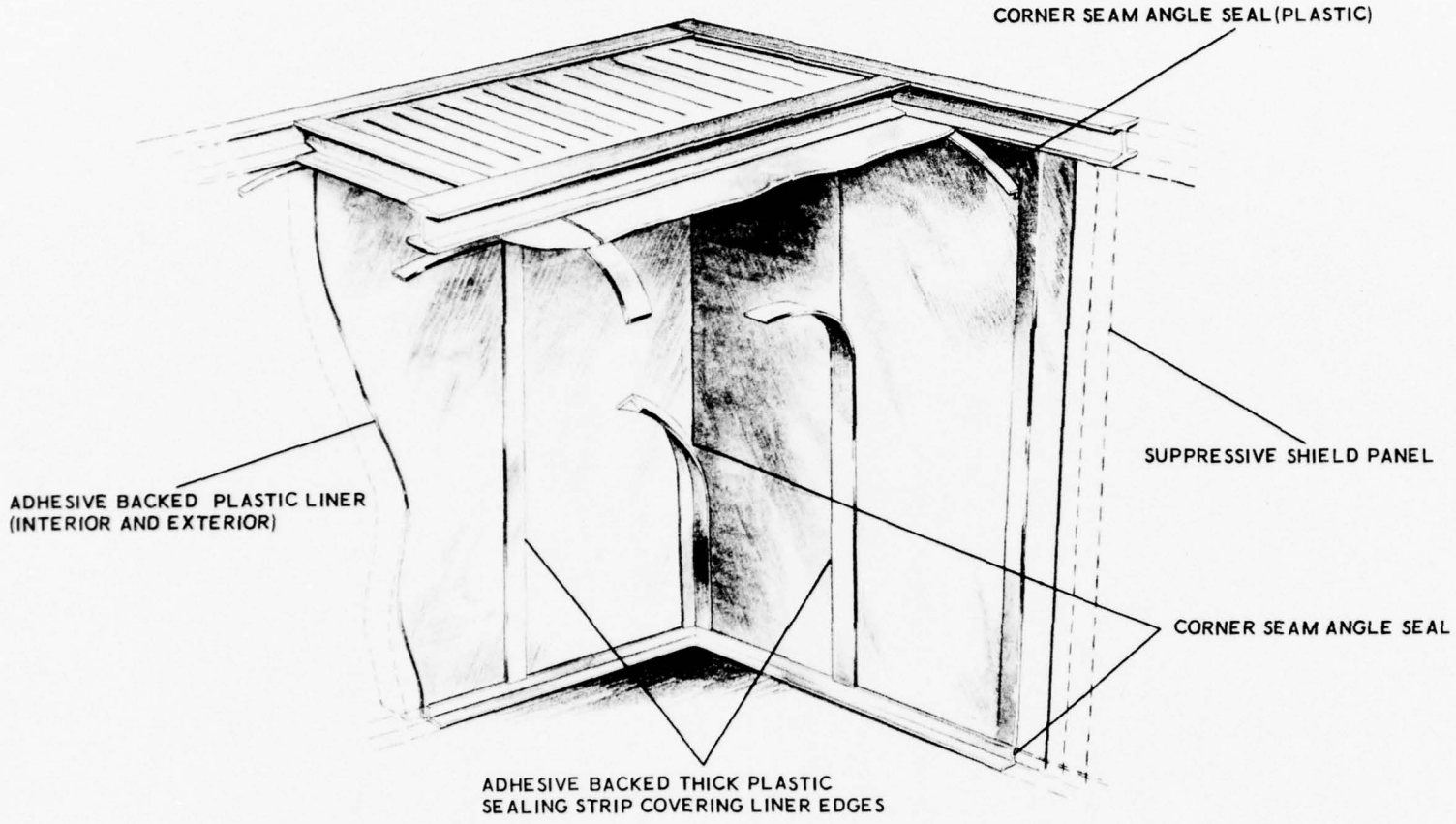


Figure 12 - Typical Installation of Thin Plastic Liners

attach the material with no wrinkles or gaps through which hazardous material can enter inaccessible regions of the panels.

D. Recommendations

Table 4 shows for each of the safety approved shields the recommended internal and external liner systems. In all cases, a sealing system has been proposed which will preclude dust accumulation or leakage around the liner. This will also keep the extreme edges of the Velostat material from pulling loose and curling.

Based on previously cited tests with sheet metal and plastic liners, and the properties of the Velostat material, it is recommended that a test series be conducted in the group 5 shield with both internal and external liners installed. The test objectives are (1) to determine the effects of internal and external liners on the structural loading and response for deflagrating materials, and (2) to determine the practicability, feasibility, and possible problems associated with attachment of thin film liners to suppressive shields.

The results and findings of this test series will be detailed in a subsequent report and included in the suppressive-shielding engineering-design handbook.

TABLE 4

SUMMARY OF PROPOSED LINERS FOR SUPPRESSIVE SHIELDS

Shield Group	Interior Liner	Exterior Liner	Attachment Method	
			Internal	External
3	Sheet Metal	Velostat	Screws & Caulk	Adhesive & Cemented Plastic Strips
4	Velostat	Velostat	Adhesive & Cemented Plastic Strips	Adhesive & Cemented Plastic Strips
5	Velostat	Velostat	Adhesive & Cemented Plastic Strips	Adhesive & Cemented Plastic Strips
81mm	Velostat	Velostat	Adhesive & Cemented Plastic Strips	Adhesive & Cemented Plastic Strips

VII. PERSONNEL DOOR.

Suppressive shields are designed to protect hazardous operations involved in the munition plant environment. These operations are hazard category III and require remote operation. Personnel will not be inside the shield during operation. However, access to the equipment involved in the hazardous operation must be provided to allow for maintenance, repair, and inspection as required. Personnel doors have been designed for each of the safety approved shields. Exits from these shields have not been designed in accordance with AMCR 385-100, Section 5-7, since no personnel will be in the shield during the operation. The door will remain open for conditions requiring personnel access.

Early shield designs contained a hinged door which swung inward. Application of suppressive shields to munition operations indicated that this inward swinging door reduced the operating space inside the shield. As a result, a sliding door was included in the group 4 shield design to eliminate interference with equipment inside the shield. This door concept was successfully proof tested in the group 4 shield. Based on these test results, the group 4 sliding door design was modified for use with the 81mm shield. Reference 5 describes in detail the sliding door design and provides engineering drawings of the 81mm shield sliding door. Safety approval has been obtained for the 81mm and group 4 shields sliding doors.

Using the same design principles, a sliding door was designed for the group 5 shield. (This shield was proof tested with a hinged door.) The sliding door design is shown in Figures 13 and 14, and calculations are provided

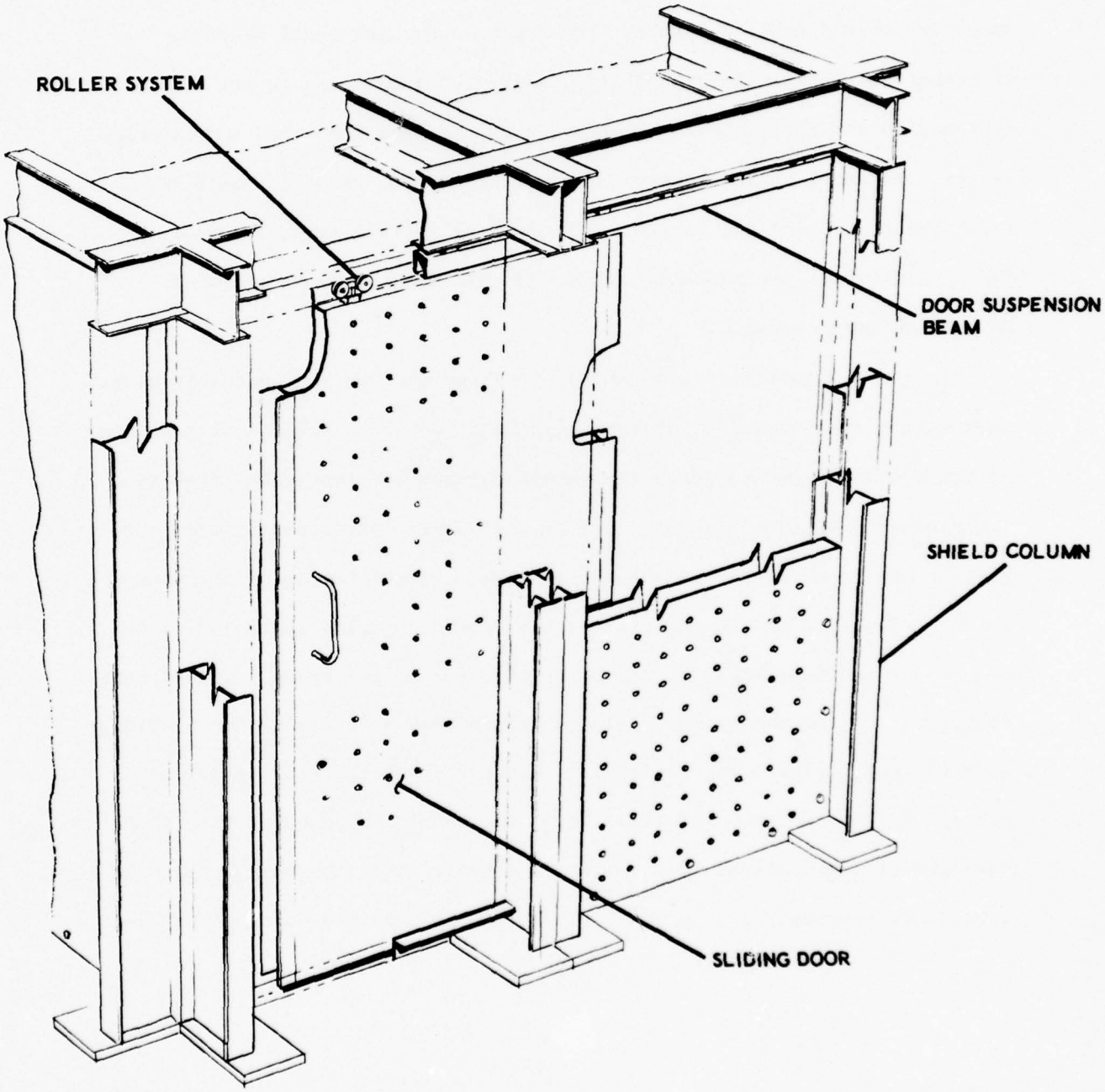


Figure 13- Sliding Personnel Door

in Appendix D. For all the sliding door designs, the door consists of an entire shield panel suspended from a beam above the panel by means of a monorail. Since the panel is inside the shield and is not rigidly attached to the shield column members, a gap between the panel and column exists. External blast pressure measurements in the group 4 shield tests indicated that increased venting did not occur in this area, apparently due to sealing of the panel/column gap by the blast pressure prior to leakage of the pressure.

The group 3 shield is cylindrical in shape and contains a double-hinged door with a total opening 4.5 feet high by 3 feet wide. The door consists of two leaves curved to match the shield contour and fabricated from S5 x 10 interlocked I-beams. Pressure loading restraint is provided by the door bearing on the external support rings at the top and bottom of the door. A latch is provided on the exterior of the door to provide restraint during rebound of the door inward. Figure 15 illustrates the group 3 shield door configuration and the Design Analysis is provided in Appendix D. A sliding door was not designed for this shield since the two-leaf configuration minimizes the clearance required inside the shield for opening this door. For special applications that require a sliding door, the design analysis procedures provided in Appendix D for the group 5 shield door can be used.

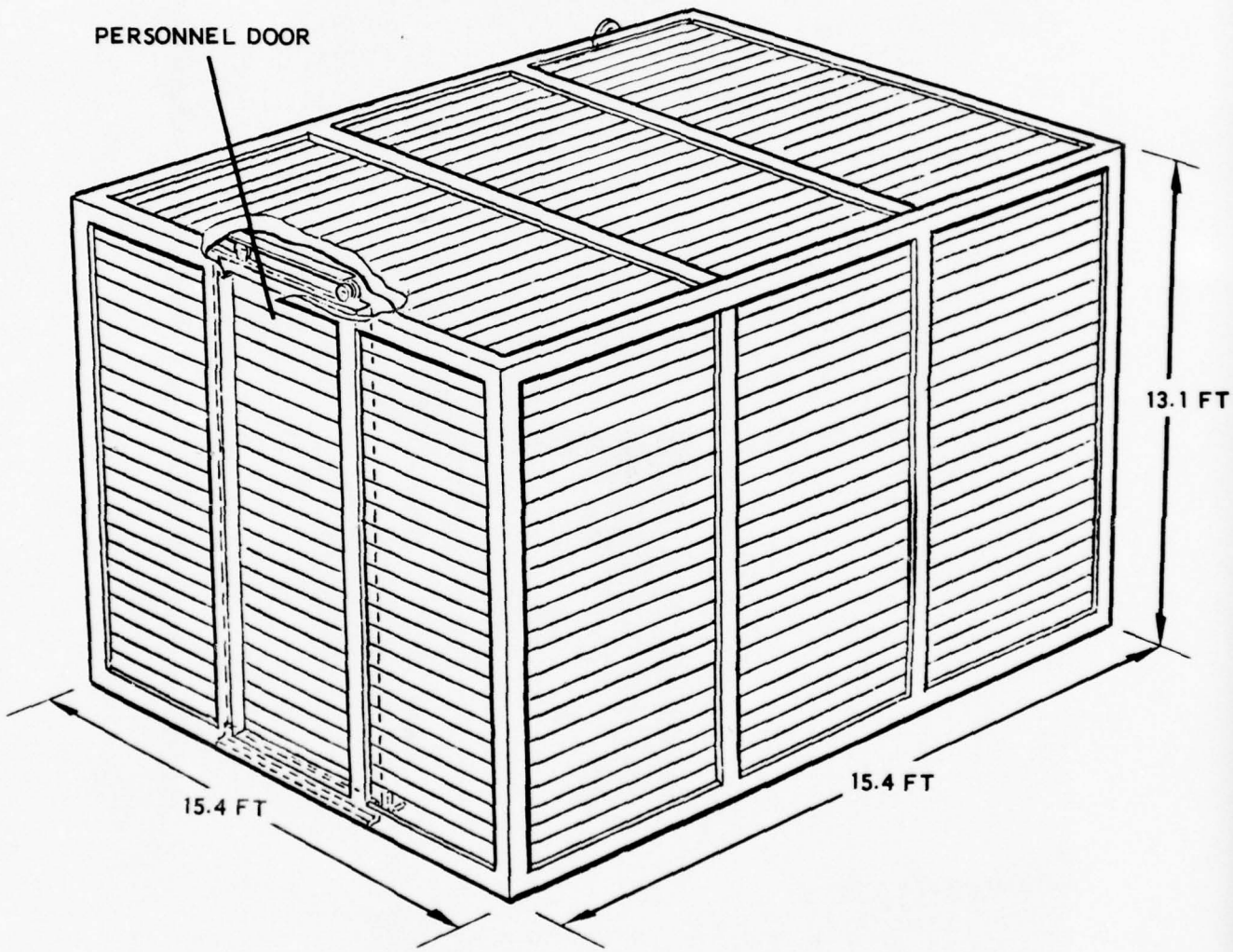


Figure 14 - Location of Personnel Door in
Shield Groups 4, 5 and 81mm

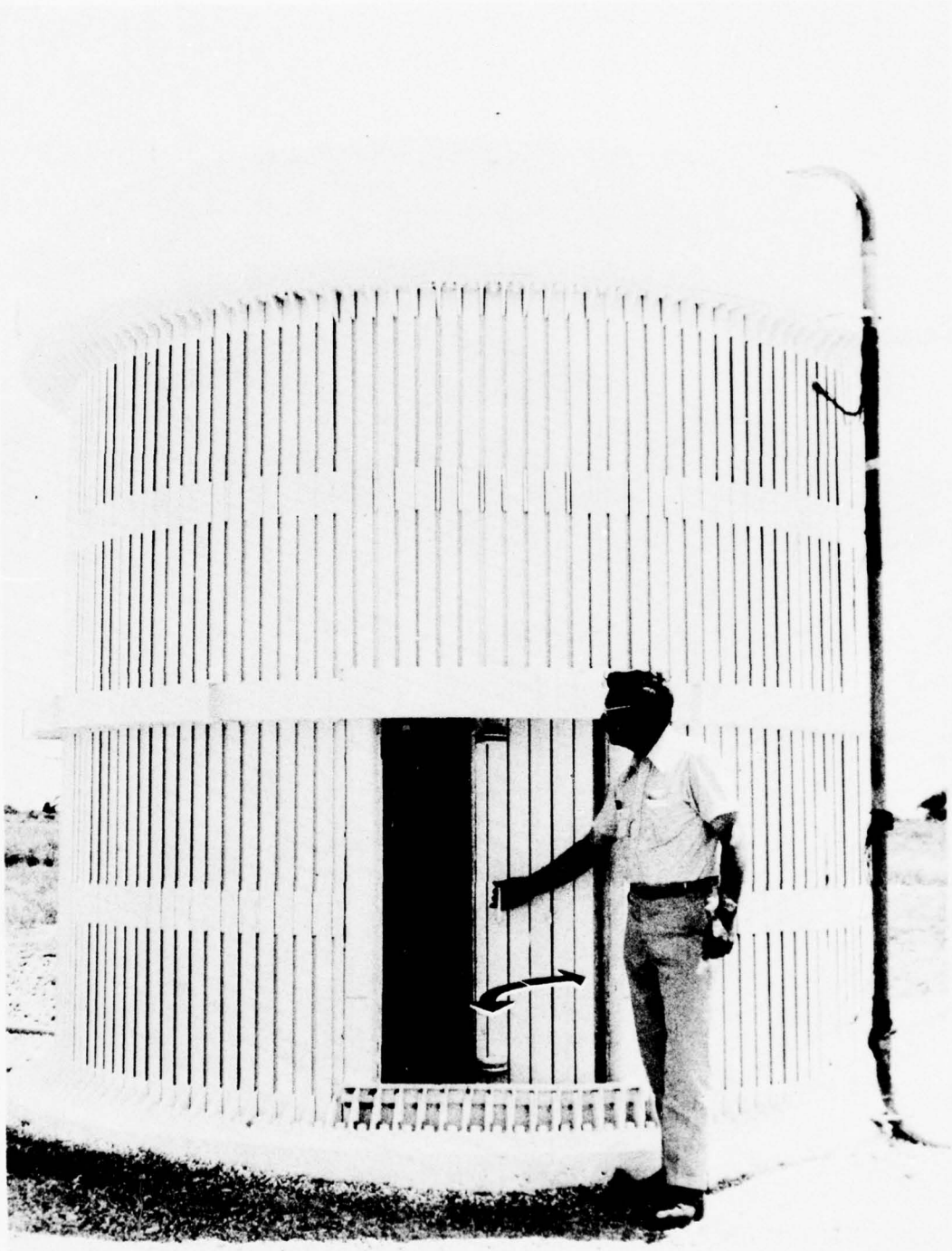


Figure 15. Hinged Door in Group 3 Shield

VIII. PRODUCT DOOR

Application of suppressive shields to munition operations requires penetrations of the shield wall for pass-through of the munition and the conveyor transporting the munition and/or munition components. A rotating product door has been designed, fabricated, proof tested, and safety approved for use in the group 4 shield and the 81mm shield. The detailed design analysis for this door is provided in Reference 5. An artist's concept is shown in Figure 16 and a typical location is shown in Figure 17.

Requirements for product doors are specialized depending on configuration of the product, pallets, and conveyors, as well as production rates and other factors unique to each operation. For these reasons, individual product doors must be designed separately for each application using the principles provided in Reference 5.

To allow use of new door designs, engineering analysis must show that the designs do not adversely affect strength or mode of response of the shield panels or wall components under the dynamic loads anticipated.

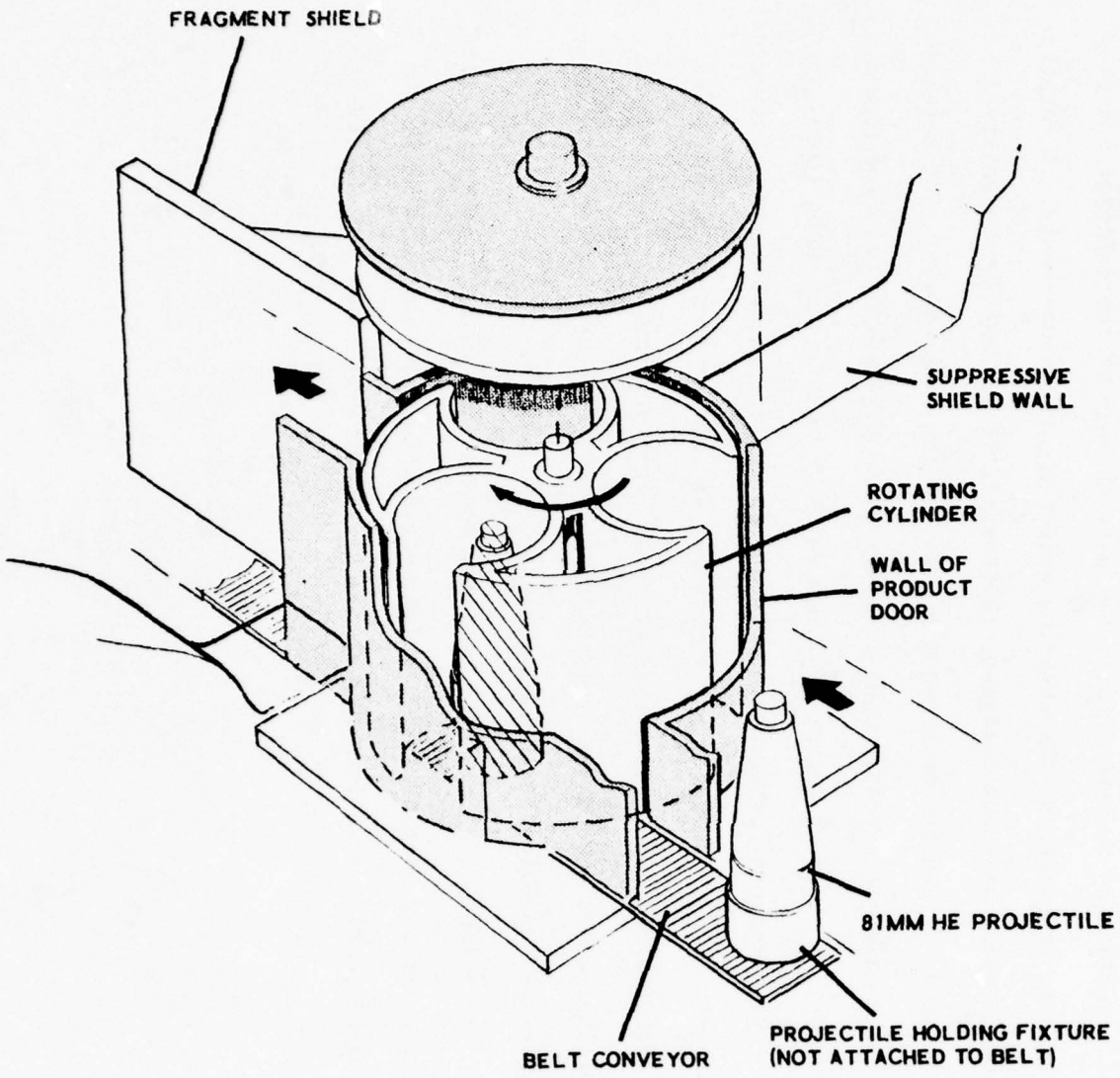


Figure 16- 81MM Product Door

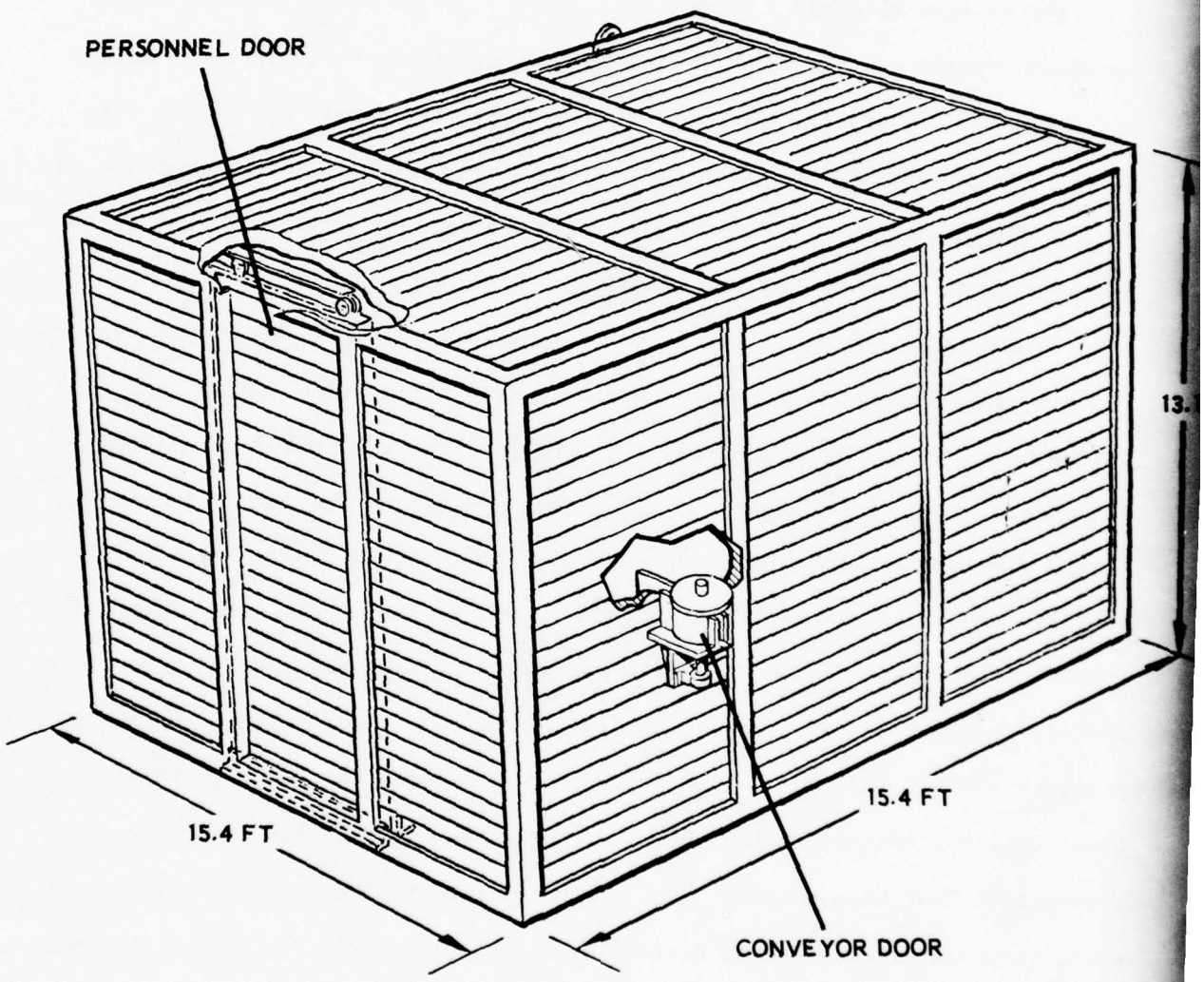


Figure 17 - Typical Location of Product Door

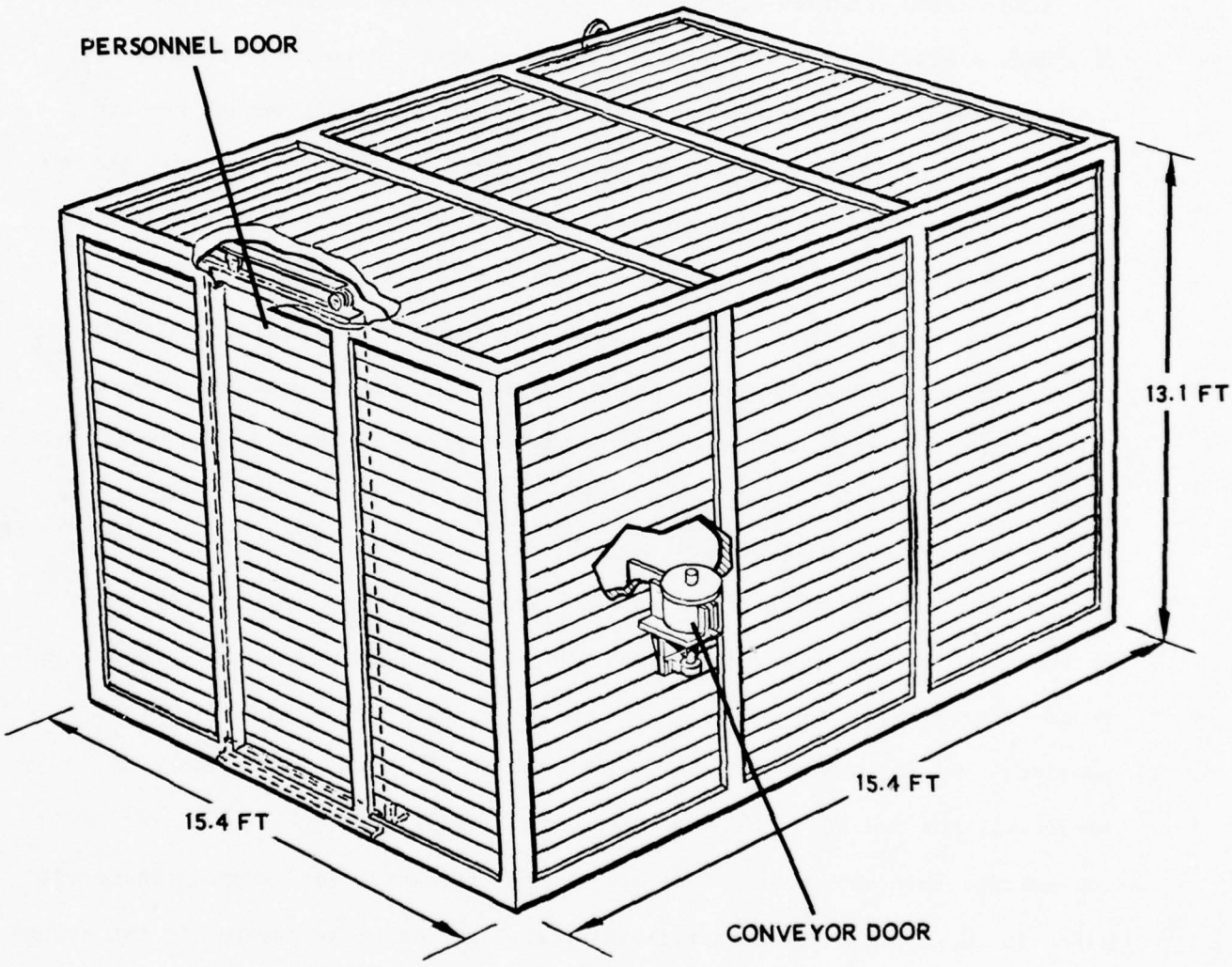


Figure 17 - Typical Location of Product Door

IX. ENVIRONMENTAL CONDITIONING PENETRATIONS

Information obtained during the AAP survey visits indicated that certain hazardous operations required special environmental control, air temperature, and humidity. To provide the necessary environmental conditioning, the air inside a suppressive shield must be changed. Since operating personnel are not present inside a shield during an explosive operation, it is not necessary to change the air to meet such requirements as provided by OSHA.

Depending upon the air conditioning requirements for a particular operation, the air can be introduced inside the suppressive shield in a number of ways. For example, it may be sufficient to use conditioned air around the outside of the shield and have it "leak" through to the inside via the spaces around the shield penetrations such as personnel and product doors. Where the air flow requirements cannot be satisfied in this manner, an inlet duct of sufficient thickness to withstand the blast loading and of such configuration to preclude fragment passage can be provided through the panels. The equipment which provides the air into the shield must be located such that the effects of blast will not endanger personnel who might normally be in the area. It is recommended that each shield have its own environmental conditioning equipment since it would probably be sacrificed or at least severely damaged in the event of an accident.

For the removal of air from inside the suppressive shield, a similar duct with the proper employment of filters (as required) to keep explosive dust from exiting the shield can be used. In operations where a waste disposal (vacuum line) system is used, this may prove to be a feasible method for exhausting air to the exterior of the shield with a duct extending as a stack through the roof. This is illustrated in Figure 18.

Sample calculations for the environmental conditioning penetration are presented in Appendix E.

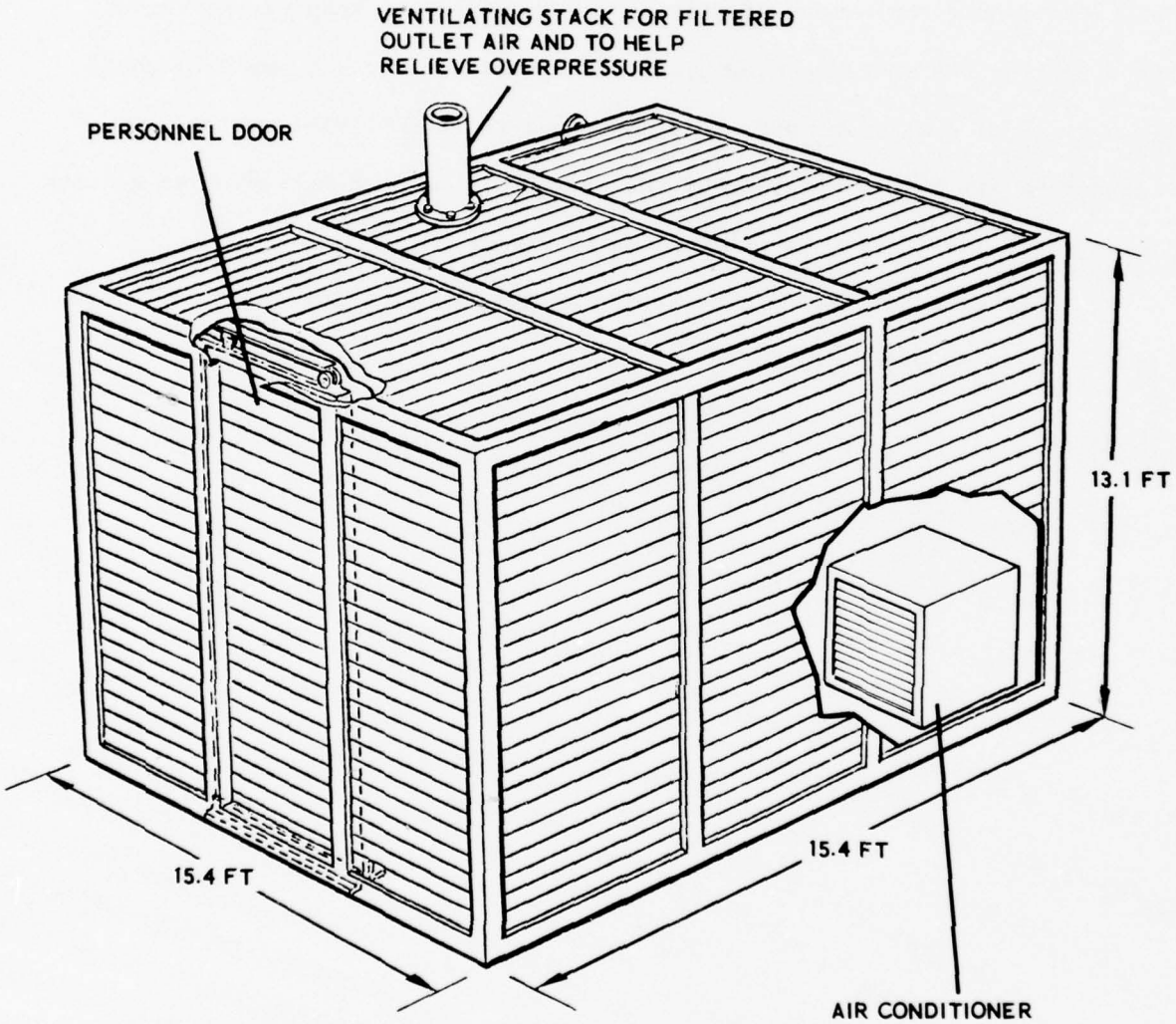


Figure 18 - Typical Environmental Conditioning Penetration

X. FINISHES

Suppressive shields will be installed in a wide variety of operating environments. These environments may include extremely corrosive acids, caustics, electrochemical reactions, gases and vapors, dusts, or other compositions which may react adversely with steel. It is virtually impossible to anticipate these environments and call out the proper specifications and procedures for surface preparation, priming, and painting of the various structural materials. Existing military and Federal specifications for finishes which are normally used in US Army ammunition plants shall be used for the suppressive shields as applicable. Applicable specifications and procedures must be a part of the technical data package prepared by the architect-engineer for a specific application and environment.

XI. DISCUSSION OF SHIELD MAINTENANCE

A. Preventive Maintenance. A typical standing operating procedure (SOP) which addresses normal periodic preventive maintenance has been prepared and is presented in Appendix F. This SOP is written without any particular Army ammunition plant (AAP) or operating environment in mind. Therefore, it must be used only as a general guide for a specific SOP requirement in a specific location and operation. Local safety, maintenance, operations, quality control policies, and procedures would necessarily dictate much of the form, format, and content of the actual SOP. In addition, the type of hazard, the environment, and other specific local conditions would also dictate the SOP content.

B. Corrective Maintenance. No specific corrective maintenance procedures have been outlined in this report since the number of possible corrections, repairs, and the like will vary with each situation. In the event that corrective maintenance is required due to damage to shield, care should be taken to consult the technical data package drawings and specifications prior to performing the maintenance. This will insure that the proper structural members, welding specifications, other material specifications, and quality control procedures are followed and that the shield will have been restored to its original structural integrity.

C. Rehabilitation and Repair. To obtain the most efficient and cost effective design, suppressive structures were developed to deform plastically when exposed to explosive blast loading. This principle is termed "limit" design." By allowing structures to plastically deform, a larger

portion of the energy from an explosive detonation can be converted into plastic work by permitting permanent deformation of the suppressive structure. This structural deformation is described by the "ductility ratio", which is the ratio of maximum deflection to maximum elastic deflection. Allowable ductility ratios are defined in terms of structural reusability. Structures with a μ less than 6 are considered reusable. This does not infer that a suppressive structure with a μ less than 6 will not require some rehabilitation and repair work after an accidental detonation within the confines of the structure. However, it does indicate that the structural members are sound and the suppressive shield will withstand another detonation.

Ductility ratios were computed for all the safety approved shields, i.e., shield groups 3, 4, 5, 6, and the 81mm, and the reusable explosive charge weight determined. Table 5 , below, lists the reusable charge weights for ductility ratios less than 6.

TABLE 5

SAFETY APPROVED SHIELDS REUSABLE CHARGE WEIGHTS

Shield	Charge Weight	TNT Equivalent
Group 3	37 lbs 50/50 pentolite	41.77 lbs.
Group 4	9 lbs 50/50 pentolite	10.16 lbs.
Group 5	1.84 lbs 50/50 pentolite	2.08 lbs.
Group 6	0.75 lb 50/50 pentolite	.85 lbs.
81mm	Two 81mm M374 mortar rounds	3.02 lbs.

All of the above listed charge weights are equal to the design charge weight for which safety approval was obtained. Therefore, all the safety approved shields are reusable for the maximum approved charge weight.

The previous discussion addressed the reuse of suppressive shields exposed to explosive blast loads. In many instances, an explosive detonation involves the generation of fragments which impact the shield surfaces and cause partial penetrations of the structural members. These penetrations can vary in size from small, superficial holes which do not affect the structure in terms of reuse or venting characteristics to large fragments that could penetrate or damage a column member and significantly affect the strength of that member. For explosive detonations involving the generation of fragments, it will be necessary to perform an engineering analysis to determine the need to replace the components of the structure. Since each shield is of unique design, the rehabilitation and repair required for each is different. For example, it would be easier and less expensive to replace a group 6 shield, whereas damage to a panel in the 81mm shield would be cost effectively repaired by replacing the panel, not the complete shield.

Procedures designed for decontamination should be performed prior to any rehabilitation and repair. All specifications defined for each shield should be followed during these operations.

The panel/frame type shields, i.e., groups 4 and 5 and the 81mm, are designed for easy replacement of entire panels or individual column members. The group 3 shield is more complex since the I-beams used to make up the cylindrical side walls are interlocked. Replacing these I-beams will require removal of the concrete roof and detachment of the I-beams from the foundation. Rehabilitation and repair of damaged shields will require this type of individual treatment.

D. Decontamination. Decontamination of the shields shall be in accordance with the local Army Ammunition Plant's SOP's, AMCR 385-100 (Safety Manual) and ARMCOM Regulation 385-5 (Contamination, Decontamination and Disposal).

Also local regulations and SOP's regarding flame permits prior to welding shall be followed. An example of a welding procedure and qualification is presented in Appendix G. This procedure is applicable to rehabilitation and repair of the shields as well as to their construction.

XII. FOUNDATIONS

A. Introduction.

Each safety approved suppressive shield has a foundation design for anchoring the structure securely in place. Shields should be prevented from excessive motion in the event of an accidental detonation to minimize damage to conveyors, utilities, and the like, that pass through the shield or to overhead structures. Shield groups 3 and 5 have been tested with concrete foundations used to anchor the shield. No motion was observed during the conduct of the proof tests of these structures after review of high speed films taken to document the tests.

B. Group 3 Shield Foundation.

The foundation used in the group 3 shield is shown in Figure 19, and is 13 feet, 4 inches in diameter, 18 inches thick, and constructed based on TM 5-1300 design procedures. The detailed design analysis is provided in Appendix H. The foundation was proof tested with 45.7 pounds of 50/50 pentolite at Aberdeen Proving Ground and only superficial cracking at the concrete surface was observed.

C. Group 4 Shield Foundation.

The group 4 shield foundation is illustrated in Figure 20. This foundation was designed to conform with a standard concrete floor existing at Lone Star AAP. Actual drawings were obtained from Lone Star AAP to determine the concrete thicknesses, rebar requirements, and concrete specifications necessary to fabricate the foundation. Due to material availability at Dugway Proving Ground (the fabrication/erection site),

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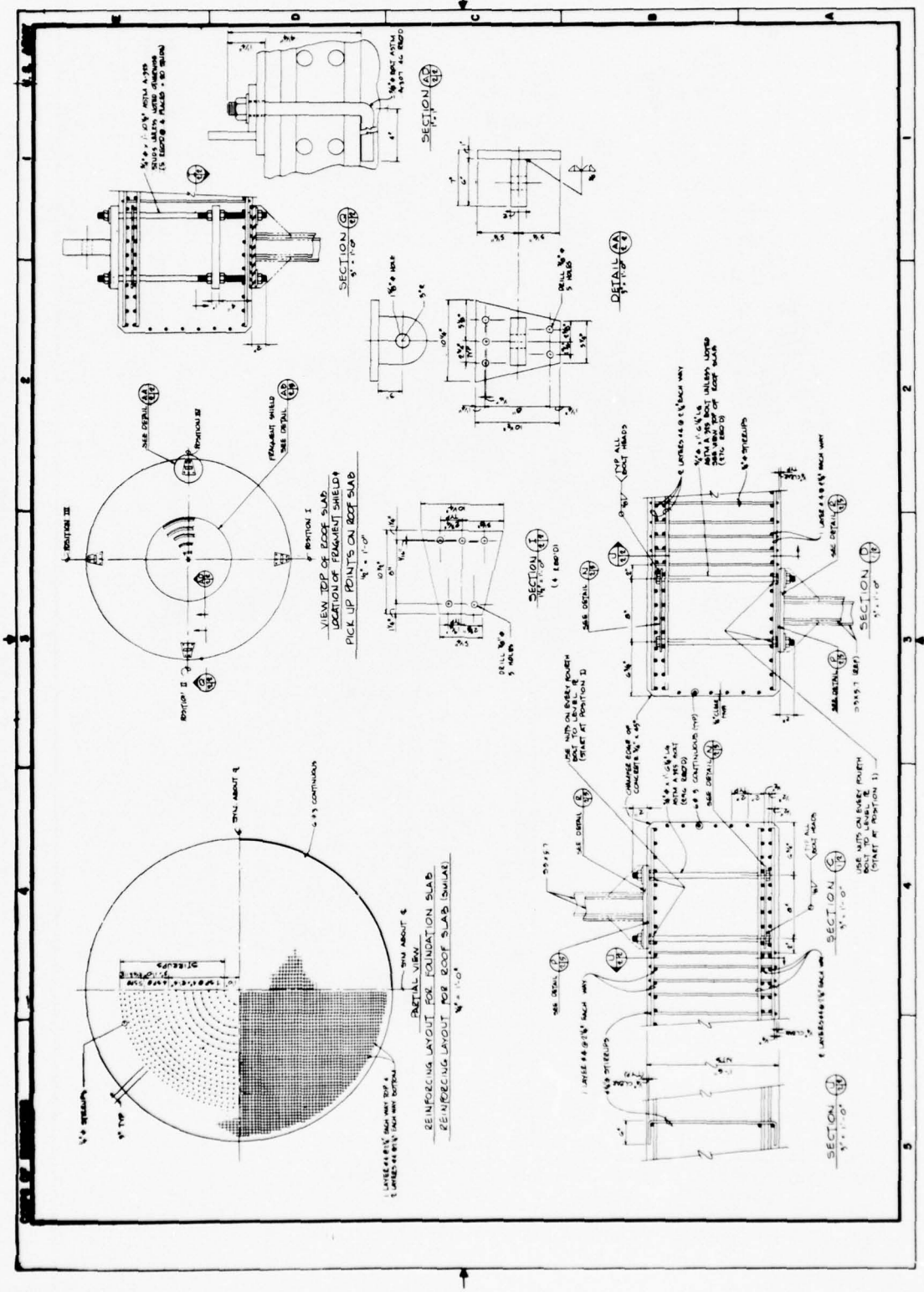

Figure 19 - Shield Group 3 Foundation Details

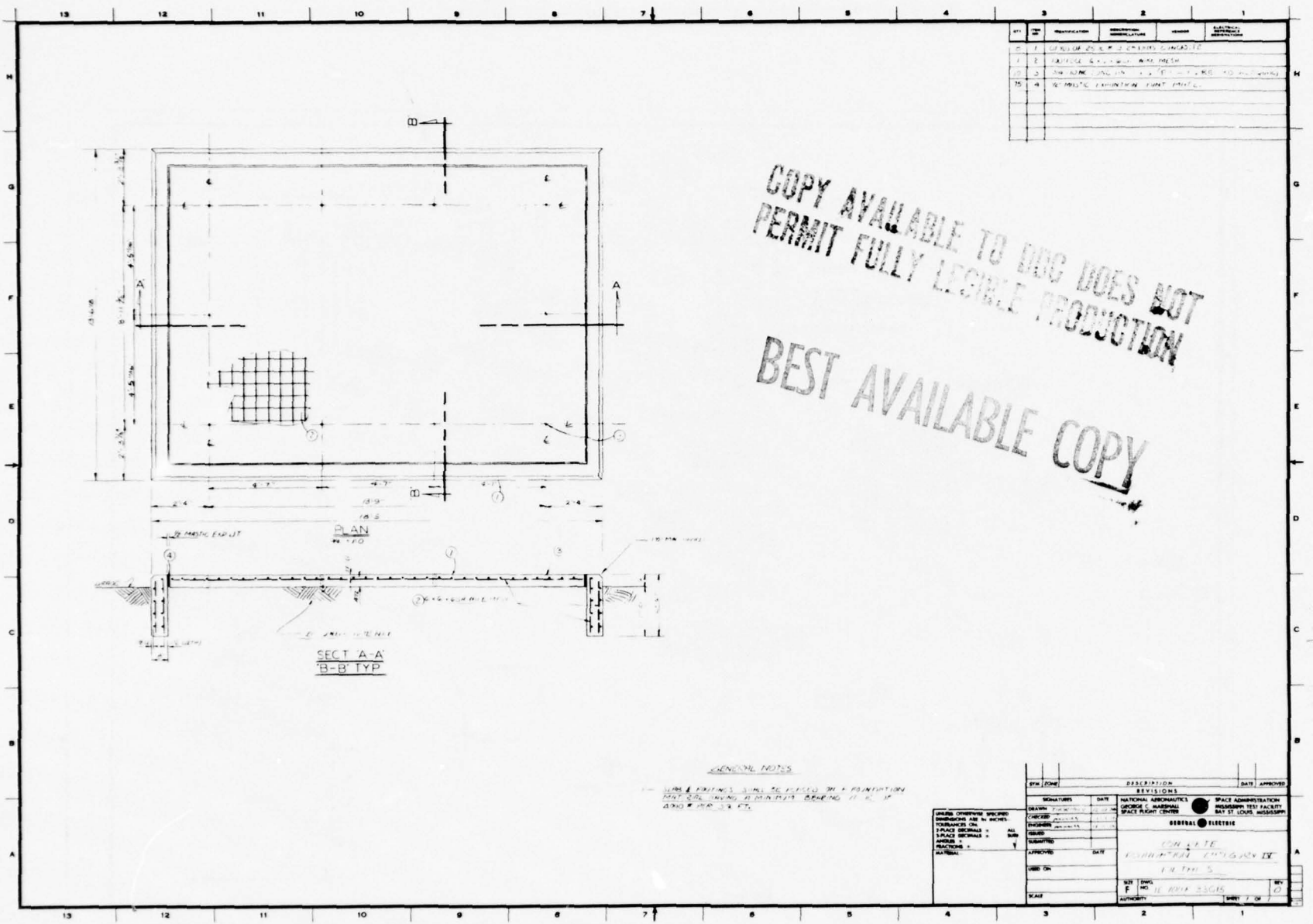

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Figure 20 - Shield Group 4 Foundation Details

the actual foundation varied from the Lone Star AAP drawings as follows: (1) Number 10 wire mesh was used instead of Number 6, and (2) the concrete skirt around the periphery was not installed. Additionally, a 3/4-inch thick steel plate was placed on the top of the concrete foundation over a wet cement grout. This installation was performed to minimize plate deflection and fragment damage to the concrete slab during repeated testing.

Tests with bare high explosive charges up to 11 pounds and two 105mm rounds were fired in the group 4 shield. Fragmentation from the two 105mm rounds was severe. Examination of the foundation after the fragment and proof test revealed some hairline cracks at the foundation periphery. The steel plate buckled in several places and was gouged from the many fragment hits. High speed motion pictures of the tests indicated a slight upward movement of the structure of from 1-2 inches. This movement could cause some problems in the operating environment and care should be taken in using this structure where shield penetrations are required. If rigid penetrations are required and if it is important that they not be damaged in an accident, then this shield should be anchored to the concrete foundation in a more rigid manner.

D. Group 5 Shield Foundation.

The foundation for the group 5 shield is a 15 feet by 15 feet and 18 inches thick monolithic reinforced concrete slab (see Figure 21).

A series of high explosive and deflagrating materials tests were conducted in the shield. The proof pressure test was conducted using 2.44 pounds of explosive. Illuminant composition charges consisting of 55 percent Sodium Nitrate and 45 percent granulated magnesium were also fired inside the shield group 5 structure. Temperatures in the range of 4000-5000°F were generated by illuminant charges of 10-50 pounds.

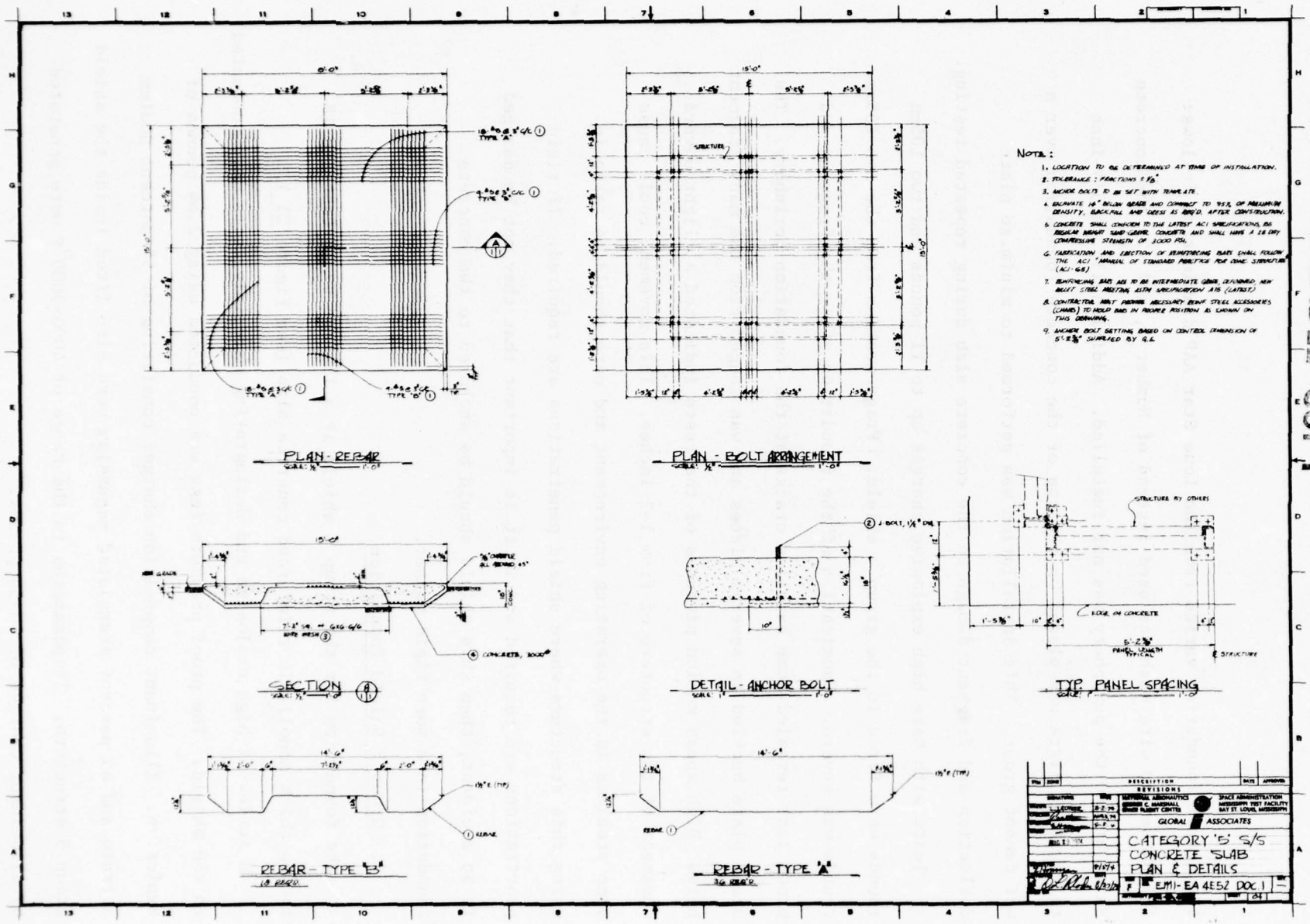

Figure 21 - Shield Group 5 Foundation Details

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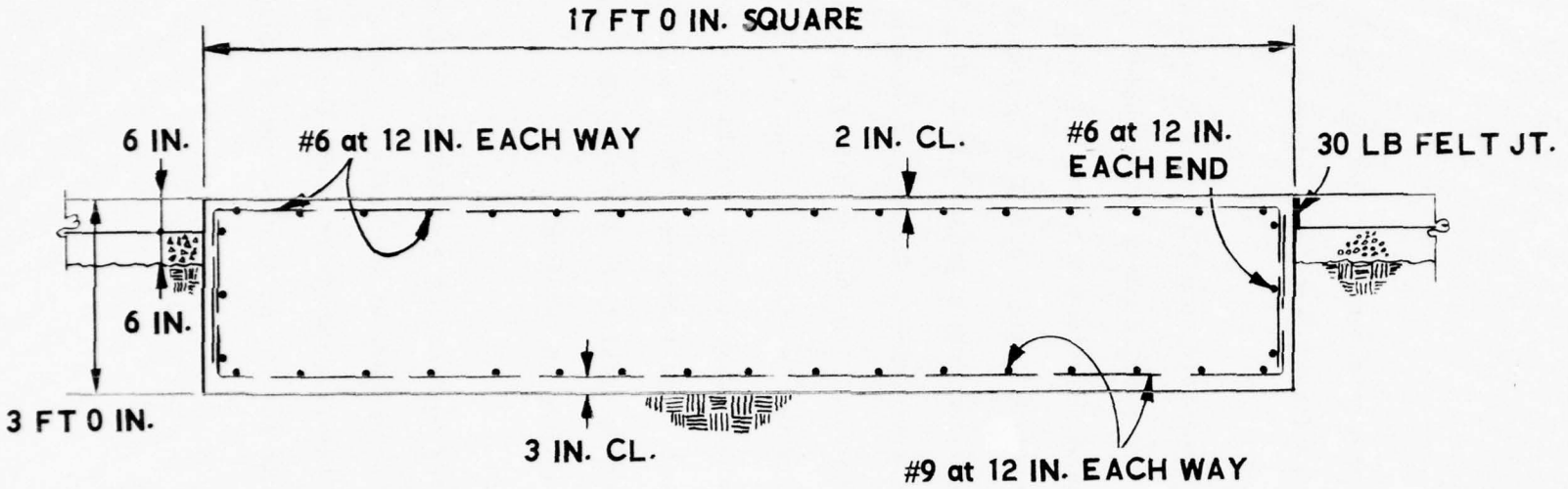
Visual examination of the concrete pad after the explosive and illuminant composition tests showed no significant cracking or deterioration of the slab.

E. 81 mm Shield Foundation

The foundation for the 81 mm shield consisted of a 1/4-inch thick steel plate welded to the bottom of the panel members which rested on a packed clay gravel base. This system was for test purposes only and was not intended as a tiedown device. This structure lifted vertically 5 inches above the ground during testing with two 81 mm mortar projectiles. To prevent this movement in an operating plant environment, the Corps of Engineers, Huntsville designed a system to anchor the shield to the concrete floor in the plant. The tiedown procedure is illustrated in Figure 22. The design analysis investigated the effect of rigidly attaching the shield to a concrete foundation and no adverse effects were indicated. The tiedown method will allow incorporation in an existing facility by removing the concrete in the tiedown locations and then replacing as required.

F. Floor Drains.

Floor drains are an integral part of the concrete foundation design. Suitable floor drains are to be designed by the Corps of Engineers, Huntsville in accordance with existing design criteria for Army ammunition plants and effluent requirements for the particular operation(s) inclosed by the shield.



FOUNDATION FOR 81 MM SUPPRESSIVE SHIELD

scale 3/8 IN. = 1 FT 0 IN.

Figure 22 -Shield Group 81MM Foundation Details

APPENDIX A - SAMPLE LETTER SENT TO AAP'S PRIOR TO SITE SURVEY

DEPARTMENT OF THE ARMY
HEADQUARTERS. EDGEWOOD ARSENAL
ABERDEEN PROVING GROUND. MARYLAND 21010

SAREA-MT-TS

SUBJECT: Suppressive Shielding Requirements Survey

Commander, Milan Army Ammunition Plant, Milan, TN 38358
Commander, Kansas Army Ammunition Plant, Parsons, KS 67357
Commander, Indiana Army Ammunition Plant, Charlestown, IN 47111
Commander, Lake City Army Ammunition Plant, Independence, MO 64056
Commander, Iowa Army Ammunition Plant, Burlington, IA 52502

1. Suppressive shields for a wide variety of hazardous munitions plant operations have been developed by our Suppressive Shielding Branch, Mechanical Process Technology Division, Manufacturing Technology Directorate, under Manufacturing Methods and Technology Project 1264. As a part of this program, which supports the US Army Munitions Production Base Modernization and Expansion Program, we have initiated an effort to obtain safety approval for interior and exterior shield liners, and for various openings and penetrations required in suppressive shields for personnel, equipment, utilities, and environmental conditioning. Inclosure 1 depicts a suppressive shield surrounding a typical munitions plant operation with the various ancillary utilities and services required for the operation.

2. The initial phase of this effort is to conduct a survey of AAP expansion and modernization projects in which suppressive shields could be effectively utilized. Based on a review of Munitions Production Base Modernization and Expansion projects scheduled for completion during the FY 78 - FY 80 time frame the following projects have been selected:

a. Lake City Army Ammunition Plant: Project 3501, 30mm GAU-8 Production Equipment (SCAMP).

b. Kansas Army Ammunition Plant: Project 2702, Detonator Facility Front Line.

c. Milan Army Ammunition Plant: Project 2709, 60/81 mm Melt System

d. Iowa Army Ammunition Plant: Project 2677, 155 mm M549, M708 and 8" x M650 LAP.

e. Indiana Army Ammunition Plant:

(1) Project 2500, 105 mm M67 Propellant Charge Load and Assembly.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

DEPARTMENT OF THE ARMY
HEADQUARTERS, EDGEWOOD ARSENAL
ABERDEEN PROVING GROUND, MARYLAND 21010

SAREA-MT-TS
SUBJECT: Suppressive Shielding Requirements Survey

(2) Project 2610, 155 mm and 8-Inch Propellant Charge Bag Loading Facility.

3. The objective of these plant surveys is to determine the requirements for specific suppressive shield applications for the projects listed above. These should be based upon hazard level of the operation as well as your needs for the equipment and process insofar as it is possible for them to be defined at this time. Inclosure 2 contains questions which are considered to be pertinent to the determination of these requirements. It is requested that they be answered, as applicable, and presented for discussion during the visit of the survey team to your plant. It is requested that drawings, specifications, sketches, and other data pertinent to your particular needs be provided to the survey team during this visit. It is also requested that Government and contractor representatives from engineering, safety, and production groups be available for discussion with the survey team, if possible.

4. The team, comprised of Mr. Douglas M. Koger and Mr. Joseph F. Voeglein from Edgewood Arsenal, and Mr. F. James Schroeder from AAI Corporation, is scheduled to conduct the survey as follows:

a. Lake City Army Ammunition Plant - 5 November 1975.

b. Kansas Army Ammunition Plant - 6-7 November 1975.

c. Milan Army Ammunition Plant - 10 November 1975.

d. Iowa Army Ammunition Plant - 17 November 1975.

e. Indiana Army Ammunition Plant - 19 November 1975.

5. Should you have any questions or desire any additional information relative to this survey or any other aspects of the project, please contact Dr. David J. Katsanis, Chief, Suppressive Shielding Branch, AUTOVON 584-2302/2661.

6. ARMCOM control number for this visit is OP-75-1015-3.

FOR THE COMMANDER:

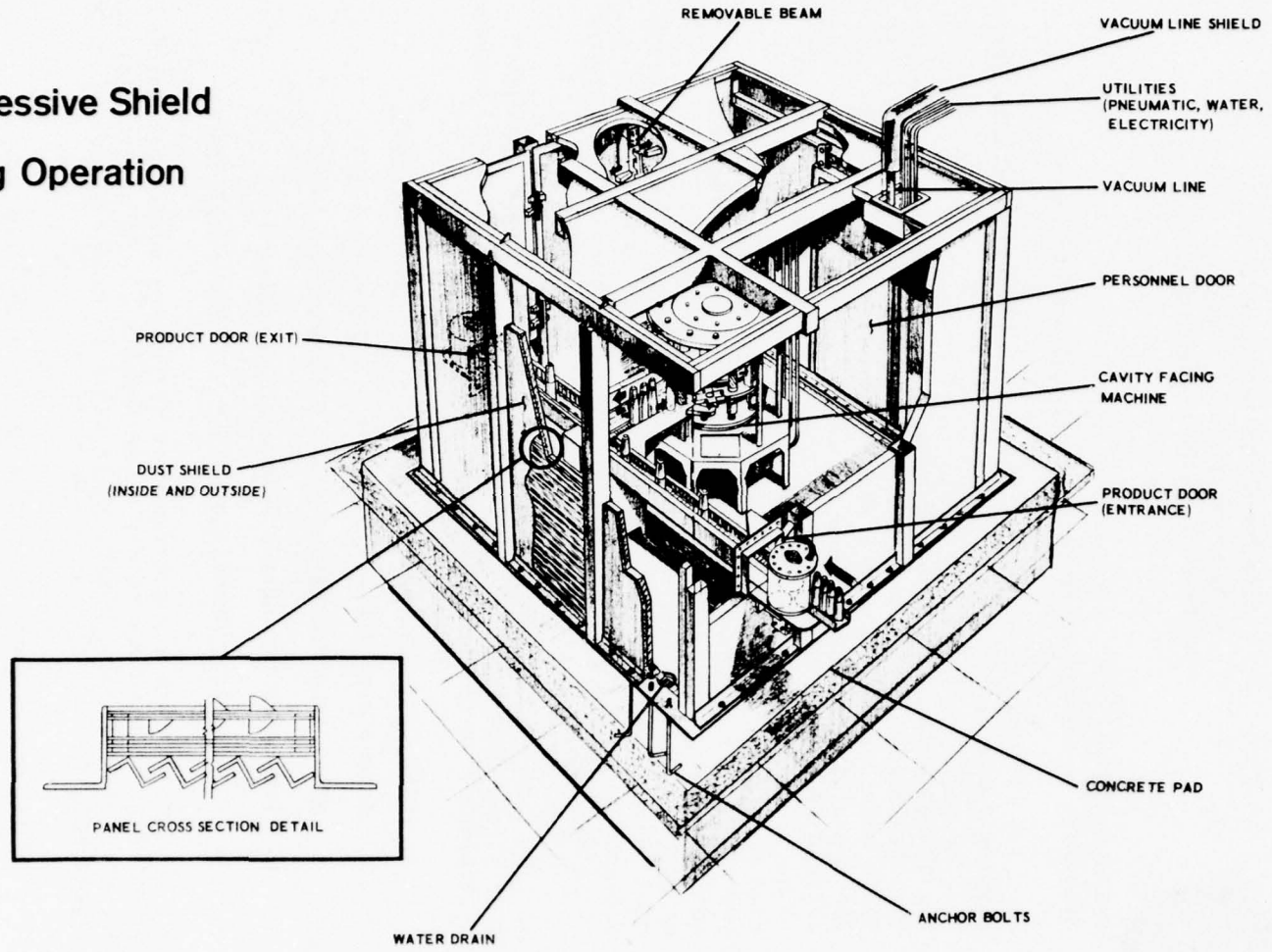
RICHARD G. THRESHER
Chief, Mechanical Process
Technology Division
Manufacturing Technology Directorate

2 Incl
1h

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

81mm Suppressive Shield

Cast Finishing Operation



REQUIREMENTS CHECKLIST

Project No. _____ Title _____

Station _____ Operation _____

Hazard Level_____ Suppressive Shield Requirement _____

Describe the hazardous operation in terms of the following:

1. What utilities do you anticipate will have to be supplied to the hazardous operation?

Utility	Requirements
Electric Power	
Compressed Air	
Vacuum	
Water	
for general use	
for deluge system	
Other	

2. What openings for entry into and exit from the shield are anticipated?

Openings	Requirements
Personnel	
Handling Equipment for Installation, etc. (i.e., forklift trucks)	
Handling Equipment for Munitions Movement (i.e., conveyors)	
Other	

3. What environmental conditioning is required in the area of the operation?

Item	Requirement
Heating	

3. (Continued)

Item	Requirement
Ventilating	
Air Conditioning	
Dehumidifying	
Other	

4. Do you anticipate the need for protective liners? Does the operation produce explosive dust? Could operations external to the shield, in the general area of the shield, produce dust or other contaminants from which the shield should be protected?

Item	Requirements
Internal Liner	
External Liner	

5. What specific interlocks would you anticipate being required for safe operation?

Interlock	Requirements
Personnel Openings	
Handling Equipment Openings	
Conveyor Openings	
Utility Penetrations	
Other	

APPENDIX B - CALCULATIONS FOR UTILITIES PENETRATIONS

Calculations for Utility Penetrations

Structural analysis of the protective box for suppressive shield utilities is based upon the conservation of energy method where the structure responds dynamically to both reflected and quasi-static pressures. (Ref. 6) Both short and long duration pressures are considered.

The following conditions are assumed to be achieved:

1) Elements do not buckle before they reach their maximum deflection

2) A bilinear resistive function.

3) The law of conservation of energy applies.

The law of conservation of energy for a multiple pulse (short and long duration) input shows that:

External Work - Internal Work = Δ Kinetic Energy

The basic structural equation is given below and relates the maximum deflection to pressure loads, structural resistance and the natural period of the structural member.

$$\left(\frac{\frac{C_1 P_m}{r_y}}{\frac{T_n \sqrt{2\mu - 1}}{\pi t_d}} \right)^2 + \frac{\frac{C_2 P_m}{r_y}}{1 - \frac{1}{2\mu}} = 1 \qquad (1)$$

Where $C_1 Pm = Pr - Pqs$

$C_2 Pm = Pqs$

Pr = reflected pressure - psi

Pqs = quasi-static pressure - psi

t_d = pulse duration for the reflected pressure - sec

T_n = natural period-sec.

μ = ductility ratio = $\frac{Xm}{Xe}$

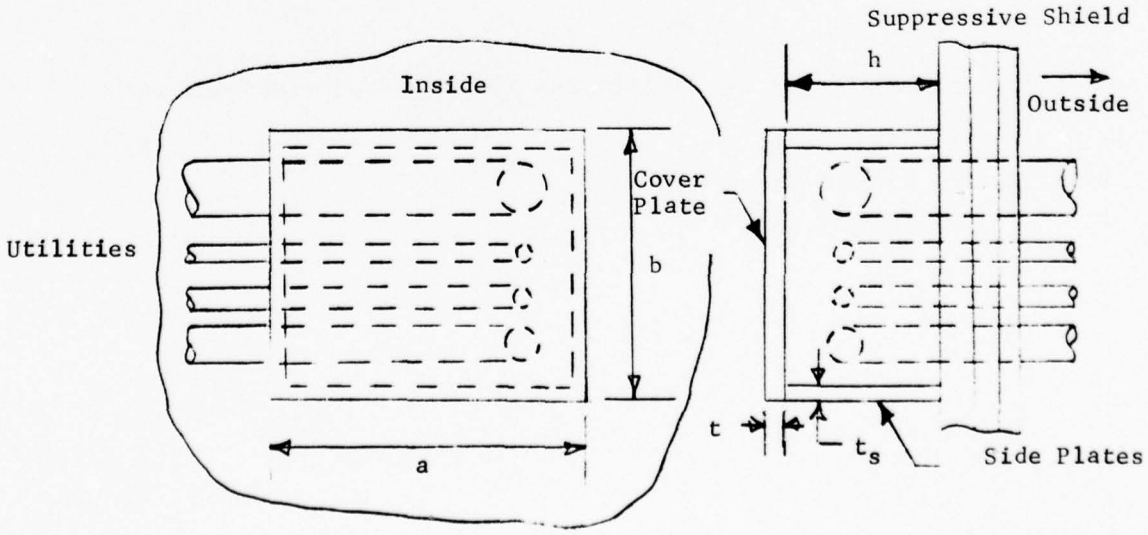
Xm = maximum deflection - in.

Xe = elastic deflection - in.

r_y = ultimate resistance of member - psi

The structural analysis considers the following areas for loading and structural response:

1. The cover plate is allowed to deform to the reuseable limit where the ductility ratio $\mu = x_m/x_e$ is less than or equal to $6(\mu \leq 6)$
2. The side plates should not buckle under the dynamic reaction load produced by the blast loading.
3. The cover plate shearing through the side plates.
4. The side plates shearing through the suppressive shield wall.



Each shield category was analyzed separately and the results for Shield Group 3 are presented below.

Shield Group 3

1. Deflection of Cover Plate

The protective box for this shield group is subjected to the following pressure levels and has the indicated dimensions.

Pressure Levels

P_r = 3198 psi

P_{qs} = 187 psi

i = .6 psi-sec = blast field impulse

Dimensions

Cover Plate: a = 10 in.

b = 20 in.

t = 1.0 in.

Side Plates: h = 8 in. Material: Mild Steel, F_{ty} KSI = 36

t_s = 1.0 in. (Ref. 7, Page 2-S) F_{tu} KSI = 55

To evaluate the ductility ratio(μ) the following parameters may be evaluated.

$C_1 P_m = P_r - P_{qs}$ = 3011 psi

$C_2 P_m = P_{qs}$ = 187 psi

The pulse duration (t_d) can be computed from the following equation

$$t_d = 2i/P_r \qquad (2)$$

substituting into equation (2)

t_d = 0.000375 sec.

The natural frequency **f** for the cover plate with short edge a, long edge b and thickness t; all edges simply supported can be calculated from the following equations. (Ref. 8, Page 579)

$$f = \frac{K1}{2\pi}\sqrt{\frac{Dg}{wa^4}} \qquad (3)$$

and $T_n = 1/f$

where:

f = natural frequency, 1/sec

T_n = natural period-sec

K_1 = constant for aspect ratio of plate $(\frac{a}{b})$

g = gravitational acceleration - 386 $in/sec.^2$

w = cover plate weight - lbs.

a = short edge - in.

$D = Et^3/\left[12(1-v^2)\right]$ - in. - lbs.

E = modulus of elasticity = 30×10^6 psi

v = Poissons Ratio = .27

t = thickness of plate - inches

For the given dimensions a and b; $\frac{a}{b} = 0.5$ and $K_1 = 12.45$

Making the appropriate substitutions into equation (3)

$$f = 1202\,t/sec$$

with $T_n = \frac{1}{f} = \frac{.00083}{t}$ sec

For $t = 1.0$ in.

$T_n = 0.00083$ sec.

The resistance of the member (r_y) can be computed from the following

$$r_y = Rm/ab \qquad (4)$$

where Rm = total load member can take-lbs.

For a simply supported plate where the ratio of short to long side $\frac{a}{b}$ = 0.5 the total load Rm may be obtained from the following equation (Ref. 6, Table 6.2A)

$$Rm = \frac{1}{a} (12\ M_p f_a + 9.0\ M_p f_b) \qquad (5)$$

Where $M_p f_a = F_{dy} Z_a$

$M_p f_b = F_{dy} Z_b$

F_{dy} = dynamic yield strength of the material-psi

Z_a = plastic section modulus about short edge

Z_b = plastic section modulus about long edge

For plates the plastic section modulus is 1.5 times the elastic section modulus (Ref. 9, Page 31)

Therefore Za = 1.5 Zae

The elastic section modulus is:

$$Zae = \frac{I}{C} = \frac{\frac{1}{12}\ at^3}{\frac{t}{2}} = \frac{a\ t^2}{6}$$

and $Z_{be} = \frac{b\ t^2}{6}$

The dynamic yield strength of the material is related to the yield strength of the material by the equation (Ref. 9, Page 16)

$F_{dy} = 1.1\ F_{ty}$

Making the appropriate substitutions into equation (5) yields

$Rm = 2.97 \times 10^5\ t^2$ (lbs.)

and $r_y = Rm/ab$

$r_y = 1485 t^2$ (psi)

Substituting the values of $C_1 P_m$, $C_2 P_m$, r_y, T_n and t_d into equation (1) yields:

$$\left(\frac{\frac{3011}{1485(1)^2}}{\frac{.00083\sqrt{2\mu - 1}}{\pi(.000375)}} \right)^2 + \frac{\frac{187}{1485(1)^2}}{1 - \frac{1}{2\mu}} = 1$$

solving for μ yields

$\mu = 5.4$ which is $\leq$ 6 for reusable members

Now $\mu = Xm/Xe$

The elastic deflection Xe can be determined from the equation

$$Xe = \frac{Rm}{Ke} \qquad (6)$$

where for $\frac{a}{b} = .5$

Ke = spring constant = $\frac{216EIa}{a^2}$ (Ref. 6, Table 6.2A)

Making appropriate substitutions this reduces to

$$Ke = \frac{18Et^3}{a}$$

substituting appropriate values into equation (6)

Xe = 0.0055 in.

with $\mu = Xm/Xe$

$\underline{Xm = 0.030 \text{ in.}}$

The total load dynamic reaction may be computed by determining the dynamic reactions at the edges of the cover plate.

For a width to length ratio (a/b) of 0.5 the dynamic reactions are

$$\left.\begin{aligned} Va &= .04P + .09R \\ Vb &= .09P + .28R \end{aligned}\right\} \qquad (7)$$

(Ref. 6. Table 6.2A)

where R = maximum resistance - lb.

P = pressure loading at time of max. structural response - lb.

The pressure loading P is dependent upon the relative values of t_d and T_m (the time to maximum deflection) (Ref. 10)

for $Tm < t_d$

$$P = \left(\frac{t_d - Tm}{t_d}\right) \quad P_r \text{ ab} + Pqs \text{ ab} \tag{8}$$

for $T_m > t_d$

$$P = Pqs \quad \text{ab} \tag{9}$$

The time to maximum deflection can be approximated from the equation

$T_m = i/r_u$

where i = impulse - psi-sec

$r_u = r_y$ = ultimate resistance - lbs.

with i = .6 psi - sec.

$r_u = 1485t^2$ (lbs.)

$T_m = 0.0004$ sec.

since $t_d = .000375$ sec.

$T_m > t_d$

and P = Pqs ab

substituting for Pqs, a and b yields

P = 37,400 lbs.

R_m = 297, 000 lbs.

Substituting values of P and Rm into equation (7) yields:

Va = 28226 lbs.

Vb = 86526 lbs.

These are the reaction forces along lengths a and b. The total loading is:

$$V_t = 2V_a + 2\ V_b$$

$$V_t = 229{,}504 \text{ lbs.}$$

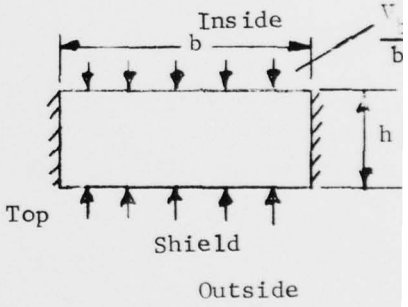
2. Buckling of Side Plates

The buckling of the side plates supporting the cover plate are analyzed the following method. Each side plate is assumed to be simply supported al edges a or b and clamped along the edges h. End loading by the reaction fo are applied along edges a or b.

Consider a plate of thickness t_s end loaded by a force, V_b.

Let σ' = critical unit compressive stress to buckle the plate (Ref. 8, Page 550)

then $\sigma' = K \dfrac{E}{1-v^2} \left(\dfrac{t_s}{b}\right)^2$ (10)



where K = constant dependent upon the span to height ratio (b/h or a/h

E = modulus of elasticity = 30×10^6 psi

v = Poissons ratio = .27

t_s = side wall thickness = 1.0 in.

For h = 8 in, b = 20 in; $\dfrac{h}{b}$ = .4 and K = 7.76

Substituting into equation (10)

σ'_b = 627,764 psi

The actual compressive stress is

$\sigma_b = \dfrac{V_b}{bt_s}$ or

$\sigma_b = 4326$ psi $< \sigma_b'$

Likewise for h = 8 in, a = 10 in; $\frac{h}{a} = .8$ and K = 6.00

and $\sigma_a' = 1{,}941{,}538$ psi

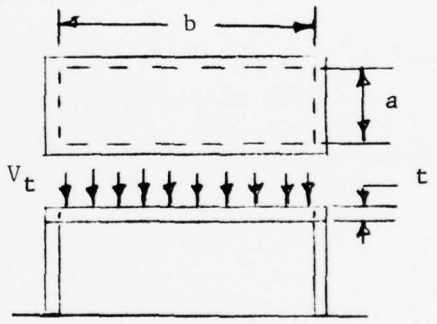
$\sigma_a = 2823$ psi $< \sigma_a'$

Therefore, none of the side plates will buckle

3. Shearing of Cover Plate Through the Side Plates

The shearing of the cover plate through the side plates is analyzed using the following method.

The total load on the plate is V_t supported by the shear area A where



$$A = 2\ t\ (a + b)$$

The shear stress is

$$S_D = V_t/A \qquad (11)$$

Substituting $V_t = 229504$ lbs.

a = 10 in.

b = 20 in.

t = 1.0 in.

SD = 3825 psi

The allowable shear stress is the dynamic shear stress of the material given by the equation (Ref. 9, Page 17)

Fdv = .55 Fdy

with Fdy = 39600 psi

Fdv = 21780 psi

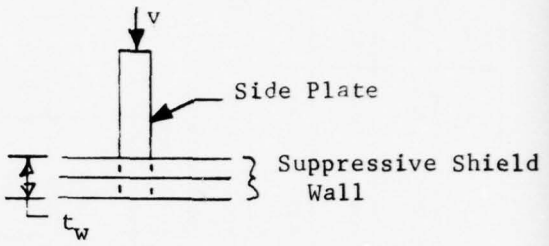
$S_D < Fdv$

Therefore, the cover plate will not shear through the side plates

4. Shearing of Protective Box Through Suppressive Shield Wall

Assume the wall is in double shear

Shear Stress = $S_w = \frac{V}{Aw}$ (12)



where V = dynamic load Va or Vb

$A_w = 2\ a\ t_w$ or $2\ b t_w$

For V_a = 28226 lbs.

a = 10 in.

t_w = 1.0 in.

Swa = 1411 psi

For V_b = 86526

b = 20 in.

t_w = 1.0 in.

Swb = 2163 psi

By inspection Swa < Fdv

Swb < Fdv

Therefore the protective box will not be pushed through the wall of the suppressive shield.

Analysis of the protective box for Shield Groups 4, 5, and 81MM follow the same method as Shield Group 3. All three final Shield Groups have an a/b ratio equal to 1 which provides a different factor of K for the natural frequency computation and a different equation for the total load (Rm) the material can carry.

For a/b = 1, Factor K for natural frequency T_n is K = 19.7 (Ref. 8, Pg. 579)

$R_m = \frac{12}{a} (M_{pfa} + M_{pfb})$, $V_a = V_b = .07P + .18R$

Spring Constant $K_e = 271 \frac{EIa}{a^2}$

Factor K for buckling analysis is K = 5.8 (Category 4)

K = 8.0 (Category 5)

K = 5.79 (Category 81 MM)

Analytical results are presented in tabular form (Figure 23) for all four shield groups.

Shield Group	P_r (psi)	P_{qs} (psi)	i psi-msec	a (in)	b (in)	t (in)	h (in)	t_s (in)	t_w (in)	t_d (sec)	T_n (sec)	R_m (psi)	r_y (lbs)	μ	X_e (in)	X_m (in)
3	3198	187	600	10	20	1.0	8	1.0	1.0	0.000375	0.00083	$2.97X\ 10^5t^2$	$1485t^2$	5.40	0.0055	0.030
4	1464	46	194	20	20	2.25	12.25	0.75	2.17	0.000274	0.00093	$2.376X\ 10^5\ t^2$	$594t^2$	0.60	0.0031	0.0019
5	493	29	55	20	20	0.50	7.5	0.50	0.43	0.000223	0.0042	$2.376X\ 10^5\ t^2$	$594t^2$	0.79	0.014	0.011
81MM	610	28	115	20	20	1.25	12.5	0.50	1.23	0.000377	0.0017	$2.376X\ 10^5\ t^2$	$594t^2$	0.61	0.0056	0.0034

Shield Group	T_m (sec)	V_a (lbs.)	V_b (lbs.)	V_t (lbs.)	σ_a' (psi)	σ_b' (psi)	σ_a (psi)	σ_b (psi)	S_D (psi)	F_{dv} (psi)	S_{wa} (psi)	S_{wb} (psi)	Notes	Original μ	μ with Box
3	0.004	28226	86526	229504	1941538	627764	2823	4326	3825	21780	1411	2163	$S_{wa} < F_{dv}$ $S_{wb} < F_{dv}$ $S_D < F_{dv}$	24.2	8.8
4	0.000065	249068	249068	996274	263928	263928	16604	16604	5535	21780	2869	2869	$S_{wa} < F_{dv}$ $S_{wb} < F_{dv}$ $S_D < F_{dv}$	3.4	3.1
5	0.00037	11504	11504	46016	161795	161795	1150	1150	1150	21780	674	674	$S_{wa} < F_{dv}$ $S_{wb} < F_{dv}$ $S_D < F_{dv}$	6.0	4.0
81MM	0.000128	78694	78694	318776	117099	117099	7869	7869	3188	21780	1600	1600	$S_{wa} < F_{dv}$ $S_{wb} < F_{dv}$ $S_D < F_{dv}$	40	35

Nomenclature

P_r = reflected pressure - psi

P_{qs} = quasi-static pressure - psi

i = blast field impulse - psi msec.

a = cover plate width - in.

b = cover plate length - in.

X_m = maximum deflection - in.

T_m = time to maximum deflection -sec

V_a = dynamic reaction along width a-lbs.

V_b = dynamic reaction along length b-lbs

V_t = total dynamic reaction - lbs.

t = cover plate thickness-in.

h = side plate height-in.

t_s = side plate thickness-in.

t_w = equivalent suppressive shield wall thickness-in.

t_d = pulse duration for the reflected pressure-sec.

σ_a' = critical unit compressive stress to buckle side plate of width a - psi

σ_b' = critical unit compressive stress to buckle side plate of length b-psi

σ_a = actual compressive stress in side plate of width a-psi

σ_b = actual compressive stress in side plate of length b-psi

S_D = shearing stress in cover plate due to total dynamic reaction-psi.

T_n = cover plate natural period-sec.

R_m = total load member can take - lbs.

r_y = ultimate resistance of member-psi.

μ = ductility ratio

X_e = elastic deflection - in.

F_{dv} = dynamic shear stress of the material-psi

S_{wa} = shearing stress in suppressive shield wall due to dynamic reaction along width a-psi

S_{wb} = shearing stress in suppressive shield wall due to dynamic reaction along length b-psi

Figure 23. Design Chart for Utility Boxes

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APPENDIX C - CALCULATIONS FOR VACUUM LINE PENETRATION

Vacuum Line Penetration Analysis

The analytical approach taken to insure the structural integrity of the vacuum line is to compute the energy of the blast loading imposed upon the vacuum line and equate this value to:

1. The amount of shear strain energy available in the flange of the vacuum line (to the material yield point).

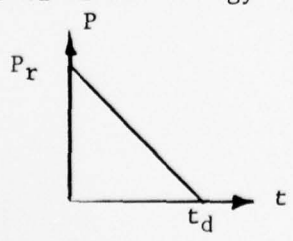
2. The amount of shear strain energy available in the shear area of the suppressive shield wall supporting the vacuum line flange (to the material yield point).

The force computed by equating the strain energies is used to evaluate the shear stress in the respective structural members. The computed shear stress is compared to the allowable dynamic shear stress to ascertain the structural integrity of the members.

The results presented below are for a particular shield (81 mm shield) and are considered conservative for reuseable members due to the fact that components are designed to preclude plastic deformation.

81MM Suppressive Shield

Consider the energy in the blast environment



with P_r = 610 psi

t_d = 0.000377 sec.

The energy is (Ref. 11)

$$E = \frac{(Hme)^2}{2m}$$

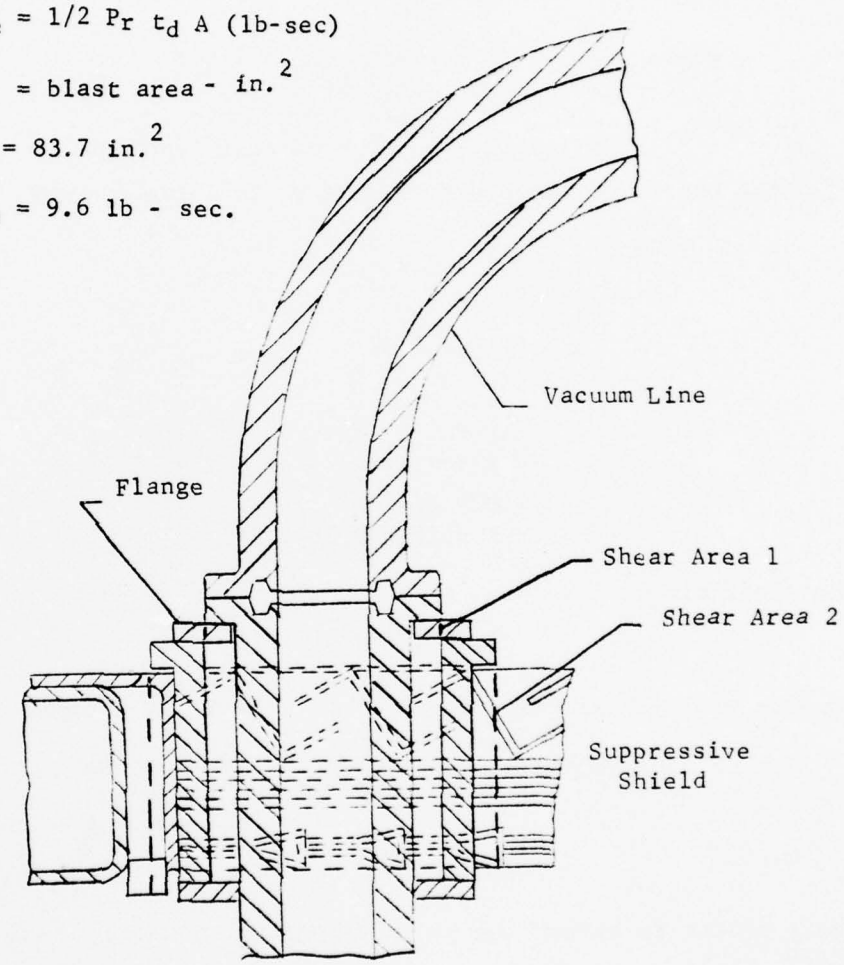
where m = mass of the loaded structure

$H_{me} = 1/2\ P_r\ t_d\ A$ (lb-sec)

A = blast area - $in.^2$

with A = 83.7 $in.^2$

H_{me} = 9.6 lb - sec.



Waste Disposal Line Weight = 120 lbs.

m = 3.73 lb-sec^2/ft.

Substituting into the energy equation yields

E = 12.35 ft. - lb. = 148.2 in. - lb.

1. Vacuum line flange - The flange of the line bears against the suppressive shield wall (Shear Area 1). The shear strain energy in the collar is:

$$U = \frac{F^2 L}{2AG}$$

where
L = shear length (in.)
A = shear area (in.^{2})
F = imposed force (lbs.)
G = modulus of rigidity (psi)

Equating the energy of the blast loading to the strain energy yields

$$E = U = \frac{F^2 L}{2AG}$$

or

$$F = \left[\frac{2EAG}{L}\right]^{1/2}$$

for

$L = .38$ in.
$A = \pi(4.75)(.38) = 5.67$ in.^{2}
$G = 11 \times 10^6$ psi
$F = 222500$ lbs.

and the shear stress

$$\sigma_s = \frac{F}{A} = 39241 \text{ psi}$$

The dynamic yield shear strength of the flange = 55% Dynamic Yield Tensile strength.

Flange Material: Cast Steel $F_y = 40{,}000$ psi

$F_{dy} = 1.1\ F_y = 44{,}000$ psi
$F_{sy} = .55_{dy} = 24{,}200$ psi

The shear stress is beyond the yield strength. However, knowing that the yield force is

$$f_y = 24200/5.67 = 137214 \text{ lb.}$$

and the yield deflection is,

$$x_e = (L)(F_{sy}/G) = .38\left(\frac{24200}{11 \times 10^6}\right) = .000836 \text{ in.}$$

It can be shown that the total deflection to absorb the blast loading energy is

$$x_m = \frac{E}{f_y} - \frac{x_e}{2} = .001078 \text{ in.}$$

The ratio $\mu = \frac{x_m}{x_e}$ is 1.29 which is well within the value of 6 which is acceptable for this application.

2. Suppressive Shield Wall - the vacuum line flange imposes a shear load on the suppressive shield wall. (Shear Area 2).

A = shear area = $4(7)(.75) = 21$ in.^{2}

$L = .75$ in.

From $$F = \left[\frac{2EAG}{L}\right]^{1/2}$$

For $A = 21$ in.^{2} (square flange)

$L = 0.75$ in.

$F = 302144$ lbs.

shear stress $\sigma_s = \frac{F}{A}$

$\sigma_s = 14388$ psi

Suppressive Shield Wall Material: $F_y \approx 36{,}000$ psi

$F_{dy} \approx 1.1\ F_y = 39{,}600$ psi

$F_{sy} \approx .55\ F_{dy} = 21780$ psi

since $\sigma_s < F_{sy}$, *the flange will not yield.*

APPENDIX D - DOOR CALCULATIONS

Design Analysis

1. Shield Group 5 Sliding Door Calculations

The door panel construction contains two sets of 2x2x1/8 inch steel angles, three layers of 16 gage perforated steel plate with 3/16 inch holes on 5/16 inch staggered spacing (32.7% open) and four layers of 16x16 mesh aluminum screen. The effective venting was calculated to be 0.028. The effect of mounting the door on track and rollers to slide horizontally has not changed the venting characteristics since no material has been added to cause additional blockage of the panel.

Door Fragmentation Protection

The equivalent metal thickness of the panel assembly to resist fragment penetration, based on the original design parameters, is 3/8 inch. The actual penetration experienced from simulated testing was considered negligible; no penetration of even the first layer of plate was observed. However, to assure that the sliding door installation is equivalent to the original design concept the total metal thickness through possible fragmentation paths was reviewed. This data is tabulated as follows:

Path	Member and Thickness	Total Thickness
Top of Door Panel	Plate 1/4", Track .150", Angle 1/4"	>1/2"
Bottom of Door	Panel Assembly 3/8", Angle 1/4"	5/8"
Sides	WF Beam 7/16", Angle 1/4" (2)	15/16"
3 Inch Diameter Hole for Latch	Panel Assembly 3/8", Bar 1/8"	1/2"

Obviously, there are no places in the installation where the fragmentation is less than the original specified requirement.

There are no cracks or openings between the door and frame when the door is closed and latched.

Track and Trolley

The weight of the door was calculated for the design analysis of the Category 5 shield dated April, 1975 and is 871 pounds. The following items are specified for the track and trolleys:

Item	Rating
McMaster Carr No. 1215A15 Trolley (2 Used)	800 lb.
McMaster Carr No. 12D7A26 Track	800 lb.

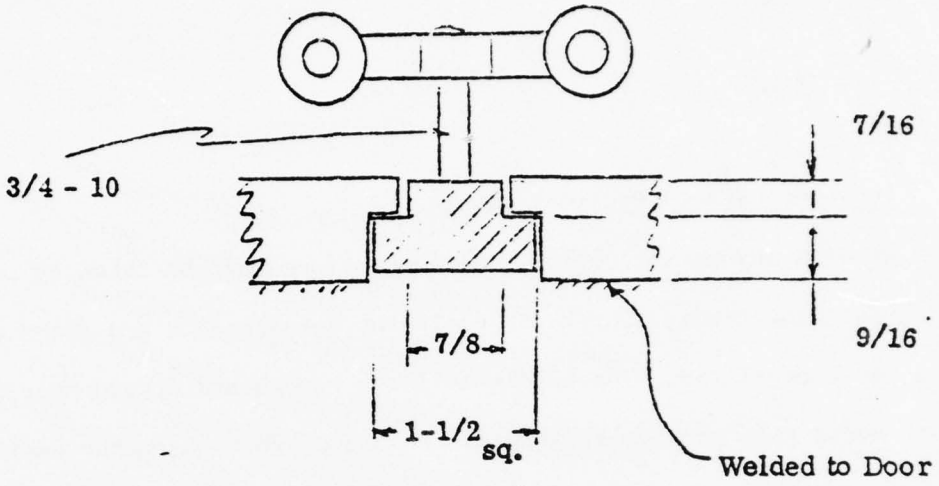
The door weight exceeds the rating by 71 pounds (8.8%) which is considered negligible, since an industrial rating of at least 4 to 1 is used for this hardware. The next size rating for the hardware would be for a 1200 pound door and may present mounting difficulties due to the much larger rollers and track. To safeguard the track against the possibility of unforeseen deflection, the track hangers have been increased to eight, spaced a maximum of 20 inches apart. The manufacturers specification for hanger spacing is 24 inches; therefore, the track support as designed will have an increased amount of strength. Because of this smaller spacing, the bending moment on the track will be reduced by approximately 16 percent. Track deflection will also be reduced. Since deflection is proportional to the fourth power of the spacing, the percentage reduction is approximately:

$$\delta, \%\ \text{RED} = \frac{l_1^4 - l_2^4}{l_1^4} \times 100 = \frac{(24)^4 - (20)^4}{(24)^4} \times 100 = 51.7\%$$

The track system is considered to be adequate based on these design assumptions.

T-Bolt Hanger and Plate

The door hangs on two trolleys. The connection is by means of two 3/4 - 10 threaded studs and sliding "T"-nut:



3/4 - 10 stud root area = 0.302 in^2

$$\text{Stress} = \frac{871}{2 \times .302} = 1442 \text{ psi (very low)}$$

$$\text{Factor of Safety} = \frac{60{,}000}{1{,}442} = 41.$$

"T"-block shear stress on 7/16" x 1-1/2" portion:

$$\text{Stress} = \frac{871}{2 \times 2 \times .4375 \times 1.5} = 331 \text{ psi (very low)}$$

The "T"-bolt hanger assembly is very conservatively designed and has very low stresses in the critical areas.

Door Latch Assembly

Two pull clamps, rated at 1000 pounds each, are used to pull and latch the door against the frame in the sliding (closed) position. In the event of an explosion, the initial and quasi-static blast pressure loads will act towards the door frame. It has been shown during actual tests that the frame safely supports the suppressive panels.

Calculate the force required to pull door closed:

$F = \mu N$, where: μ is the frictional coefficient (0.75 for dry steel)

N is the normal force on the "T"-slot bearing surface

F is the frictional force

$F = (.75 \times 871) = 653.25$ pounds

The clamps are adequate for this function and have a good reserve of force available for latching the door.

Personnel Safety Considerations

As with any moving device, due precautions must be taken by personnel to avoid catching hands, fingers or equipment between door and frame when sliding the door closed. The handle is large enough and spaced away from the panel to avoid this problem so long as the hands are kept on the device. It is recommended that a warning sign be attached on the door, or the edges of the door be painted with a safety stripe, according to customary AAP procedures.

References

EM-TM-76001, Category 5 Suppressive Shield, May 1975, D. M. Koger and G. L. McKown

Design Analysis of a Suppressive Structure for a Category 5 Operational Shielding Application, April 1975, R. E. Wandrey

Manual of Steel Construction, AISC, Seventh Edition

AD-A037 414 AAI CORP BALTIMORE MD F/G 13/13

ENGINEERING DESIGN GUIDELINES, DRAWINGS AND SPECIFICATIONS FOR --ETC(U)

DEC 76 F J SCHROEDER, R L KACHINSKI DAAA15-75-C-0120

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2 OF 3

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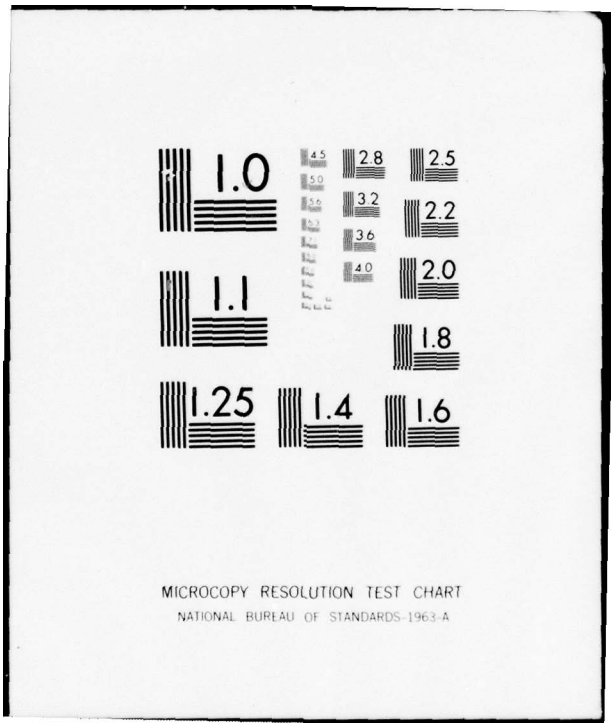
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

U. S. ARMY
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

(2) Shield Group 3 Door Calculations

SUBJECT:	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

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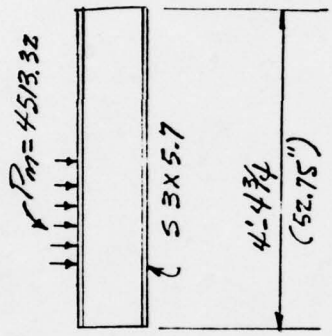
Door



$$\left[\frac{C_1 P_m}{\frac{r_y}{F_1}}\right]^2 + \frac{C_2 P_m}{\frac{r_y}{F_2}} = 1$$

$$\left[\frac{.9483(4513.32)}{\frac{235.47}{F_1}}\right]^2 + \frac{.0517(4513.32)}{\frac{235.47}{F_2}} = 1$$

$$\left(\frac{18.176}{F_1}\right)^2 + \frac{.9909}{F_2} = 1$$

$$\left(\frac{18.176}{105.69}\right)^2 + \frac{.9909}{1.016} = 1$$

$$1.005 \approx 1$$

$M_p = f_{sp} = 42{,}000(1.95) = 81{,}900$ "#

$M = \frac{wl^2}{8}$ $\quad w = r_y$

$r_y = \frac{8M}{l^2} = \frac{8(81{,}900)}{(52.75)^2} = 235.47$ (PROVIDED)

$T = 0.64 L^2 \sqrt{\frac{W}{gEI}}$

$T = 0.64(52.75)^2 \sqrt{\frac{5.7}{12(386)(30)(10^6)(2.52)}}$

$T = .00718$

TRY $\mu = 110$

$F_1 = \frac{T}{\pi t_{d_1}} \sqrt{2\mu - 1}$

$F_1 = \frac{7.18}{\pi(.32)} \sqrt{2(110)-1} = 105.69$

$F_2 = \frac{T}{\pi t_{d_2}} \sqrt{2\mu - 1} + \frac{1 - \frac{1}{2\mu}}{1 + .7\left(\frac{T}{t_{d_2}}\right)}$

$F_2 = \frac{7.18}{\pi(1404)} \sqrt{2(110)-1} + \frac{1 - \frac{1}{2(110)}}{1 + .7\left(\frac{7.18}{1404}\right)}$

$F_2 = 1.016$

110 μ IS TO HIGH ∴ REVISE DOOR SECTION

```
UTP5      09:57  ATL WED   12/03/75.

ENTER PM,C1,C2,T1,T2,PERIOD

INPUT:00190
 ? 4504.5,.9483,.0517,.00032,1.404,.007147

ENTER INCREMENT OF MU ( .1,1,ETC )

INPUT:00220
 ? 5

  MU      RY
 1.00    875.03
 6.00    347.48
11.00    300.04
16.00    280.43
21.00    269.48
26.00    262.42
31.00    257.46
36.00    253.76
41.00    250.88
46.00    248.57
51.00    246.66
56.00    245.06
61.00    243.69
66.00    242.51
71.00    241.47
76.00    240.55
81.00    239.72
86.00    238.98
91.00    238.30
96.00    237.69
01.00    237.12
06.00    236.60

RUNNING TIME:     3.1 SECS   I/O TIME :     1.7 SECS
```

DOOR LENGTH 52.75"

7A

U. S. ARMY
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

ADD COVER PLS TO DOOR BMS (S3X5.7) TO REDUCE μ

TRY COVER PLS 1½" WIDE X ¼" THICK

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$$\text{TOTAL } I_T = I_{BM} + I_{PLS} = 2.52 + 2\left[\frac{bh^3}{12} + ad^2\right]$$

$$I_T = 2.52 + 2\left[\frac{1.5(.25)^3}{12} + .375(1.625)^2\right]$$

$$I_T = 4.50$$

$$S_P = \frac{4.50}{1.75}\left(\frac{1.95}{1.68}\right) = 2.99 \text{ IN}^3 \quad (S_P,\ S_E)$$

$$M_P = f S_P = 42{,}000\ (2.99) = 125{,}580 \text{ IN-LB}$$

$$M_P = \frac{wL^2}{8} \qquad w = r_y \qquad r_y = \frac{8(125{,}580)}{(52.75)^2} = 361 \#/\text{LIN. IN}$$

$$W = 5.7 + 1.28(2) = 8.26$$

$$T = 0.64\, L^2 \sqrt{\frac{W}{gEI}}$$

$$T = 0.64(52.75)^2 \sqrt{\frac{8.26}{12(386)(30)(10^6)(4.50)}} = .0065$$

$$\left[\frac{C_1 P_m}{\frac{r_y}{F_1}}\right]^2 + \frac{C_2 P_m}{\frac{r_y}{F_2}} = 1$$

$$\left[\frac{.9483(4513.32)}{\frac{361}{F_1}}\right]^2 + \frac{.0517(4513.32)}{\frac{361}{F_2}} = 1$$

$$\left(\frac{11.85}{F_1}\right)^2 + \frac{.646}{F_2} = 1$$

$$\left(\frac{11.85}{23.31}\right)^2 + \frac{.646}{.93} = 1$$

$$.953 \leq 1 \quad \text{OK} \quad \mu \cong 6.5$$

TRY $\mu = 7$

$$F_1 = \frac{I}{\pi t d_1}\sqrt{2\mu - 1} = \frac{6.5}{\pi(.32)}\sqrt{2(7)-1} = 23.31$$

$$F_2 = \frac{I}{\pi t d_2}\sqrt{2\mu - 1} + \frac{1 - \frac{1}{2\mu}}{1 + .7\left(\frac{I}{td^2}\right)}$$

$$F_2 = \frac{6.5}{\pi(1.404)}\sqrt{2(7)-1} + \frac{1 - \frac{1}{2(7)}}{1 + .7\left(\frac{6.5}{1.404}\right)}$$

$$F_2 = .93$$

```
UTP5        15:01   ATL WED   12/03/75

ENTER PM,C1,C2,T1,T2,PERIOD

INPUT:00190
 ? 4504.5,.9483,.0517,.00032,1.404,.0064

ENTER INCREMENT OF MU ( .1,1,ETC )

INPUT:00220
 ? 1

 MU      RY
  1.00     939.92
  2.00     570.94
  3.00     469.54
  4.00     418.47
  5.00     386.84
  6.00     365.01
  7.00     348.91
  8.00     336.47
  9.00     326.53
 10.00     318.38
 11.00     311.56
 12.00     305.77
 13.00     300.78
 14.00     296.43
 15.00     292.60
 16.00     289.20
 17.00     286.16
 18.00     283.42
 19.00     280.94
 20.00     278.69
```

NEW DOOR MEMBER

8A

SUBJECT:	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

CALCULATE REACTION AT END OF VERTICAL MEMBER IN DOOR

$V_d = .38 R_m + 0.12F$

$V_d = .38(249.7 \times 52.75 \times 1.43) + .12(52.75 \times 163 \times 1.43)$

$V_d = 8633\#$

$r_y = \frac{9.20 f_{dy} S}{bL^2}$ $\quad \frac{4.50}{1.75}$

$r_y = \frac{9.20(42{,}000)(2.57)}{1.43(52.75)^2}$

$r_y = 249.7$ PSI

SHEAR CAPACITY OF BM = 12.75^k SEE SH. 1C

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SUBJECT:	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

TRY LARGER BEAM IN DOOR SO THAT COVER PLATES WILL NOT BE REQUIRED.

TRY S5X10

$P_m = 3(3150) = 9450$

$C_1 = .9483$

$C_2 = .0517$

$M_p = f_{sp} = 42{,}000\,(5.67) = 238{,}140''^{\#}$

$m_p = \frac{wl^2}{8}$ $\quad r_y = w$ $\quad r_y = \frac{8\,(238{,}140)}{(52.75)^2} = 684.66\ \#/\text{LIN. IN.}$

$$T = 0.64\,L^2\sqrt{\frac{W}{gEI}}$$

$$T = 0.64\,(52.75)^2\sqrt{\frac{10}{12(386)(30)(10^6)12.3}} = .0043$$

$$\left[\frac{\frac{C_1 P_m}{r_y}}{F_1}\right]^2 + \frac{\frac{C_2 P_m}{r_y}}{F_2} = 1$$

$$F_1 = \frac{T}{\pi t d_1}\sqrt{2n-1}$$

$$F_1 = \frac{.43}{\pi(.32)}\sqrt{2n-1} = 4.28\sqrt{2n-1}$$

$$F_2 = 1 - \frac{1}{2n} = \frac{2n-1}{2n}$$

$$\left[\frac{\frac{.9483(9450)}{684.66}}{4.28\sqrt{2n-1}}\right]^2 + \frac{\frac{.0517(9450)}{684.66}}{\frac{2n-1}{2n}} = 1$$

$$\frac{9.35}{2n-1} + \frac{.714(2n)}{2n-1} = 1$$

$$\frac{9.35 + 1.427n}{2n-1} = 1$$

$$9.35 + 1.427n = 2n - 1$$

$$10.35 = .573\,n$$

$$n = 18$$

REACTION (DYNAMIC)

$V = .38\,R_m + .12\,F$

$V = .38(684.66)(60) + .12(60\times163\times\tfrac{1}{2})$

$V = 19{,}131^{\#}$

BEAM CAPACITY

$V = 5(.214)(25{,}000) = 26{,}750^{\#}$ OK

```
READY
RUN

ITP2A     09:54  ATL VED   12/17/75

ENTER PM,C1,C2,T1,T2

INPUT:0032C
 ? 945C,.9483,.0517,.00032,1.404

DO YOU WANT PROGRAM TO CALCULATE T AND PY?
ENTER 1 FOR YES, 0 FOR NO

INPUT:0038C
 ? 1

ENTER 1 FOR SIMPLY SUPPORTED, 2 FOR FIXED ENDS

INPUT:0043C
 ? 1

ENTER W,XI,X2,YL,FIY,ENOI

INPUT:0048C
 ? .933,12.3,5.67,52.75,42000,30000000

PY=    6.8466386648E+02
T=    4.2539037109E-03

T1/T=    7.4698224235E-02
T2/T=    3.2773845893E+02
ENTER DEL

INPUT:0083C
 ? .2

IREC=          1
JREC=          2
F1=    2.5245989198E+01
F2=    9.7598098196E-01
      C1PM/PY/F1          C2PM/PY/F2          SUM                 MU
          0.2688              0.7311              0.9999          18.0500
```

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8D

```
ENTER 1 FOR SIMPLY SUPPORTED, 2 FOR FIXED ENDS

INPUT:00430
 ? 1

ENTER W,XI,XZ,XL,FDY,EMOD

INPUT:00480
 ? 1.229,15.2,7.42,52.75,42000,30000000

RY=    8.9597987466E+02
T=    4.6808411506E-03

T1/T=    6.8363781144E-02
T2/T=    2.9994608977E+02
ENTER DEL

INPUT:00830
 ? .2

IREC=          1
JREC=          2
F1=    1.5686316277E+01
F2=    9.2046377771E-01
       C1PM/RY/F1          C2PM/RY/F2          SUM                 MU
           0.4066              0.5924              0.9990              6.1750

ENTER 1 FOR SIMPLY SUPPORTED, 2 FOR FIXED ENDS

INPUT:00430
 ? S

RUNNING TIME:    6.0 SECS   I/O TIME :    3.9 SECS

READY
BYE

OFF AT 10:01

€
```

S5 X 14.75

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BE

SUBJECT.	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

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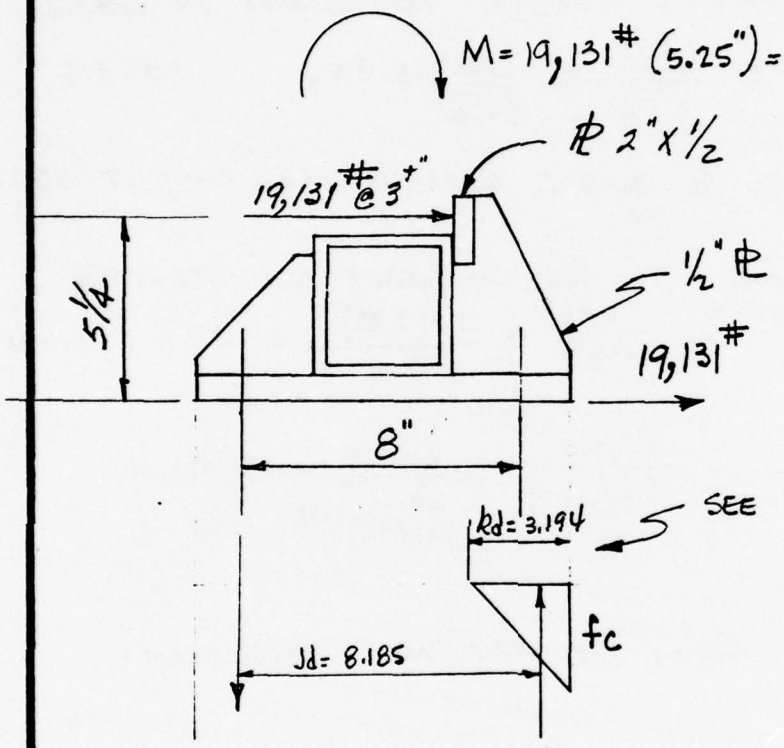
$M = 19{,}131^{\#}(5.25") = 100{,}437.75^{"\#}$



SEE PREVIOUS CALCULATIONS

$A_T = .334^{\square"}$

$A_S = .442^{\square"}$

FORCE IN A.B. $= \frac{100{,}437.75}{8.185} = 12{,}271^{\#}$

STRESS IN A.B. (TENSION) $= \frac{12{,}271^{\#}}{.334^{\square"}} = 36{,}739$ PSI

SHEAR STRESS $= \frac{19{,}131}{2(.442)} = 21{,}652$ PSI $< 25{,}000$ OK

(2 ← NO. BOLTS)

F_T ALLOWABLE $= 85 - 1.6 f_v = 85 - 1.6(21.6) = 50.44$ KSI > 36.7 KSI OK

PG 14
APPLIED PLASTIC DESIGN IN STEEL

SUBJECT:	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

CHECK UNSUPPORTED LENGTH OF BEAMS IN DOOR

$$\frac{\text{WIDTH}}{\text{THICKNESS FLG.}} \leq \frac{52.2}{\sqrt{Fy}} = \frac{52.2}{\sqrt{42}} = 8.05 \qquad 53 \times 5.7$$

$$\frac{1.08}{.26} = 4.15 \leq 8.05 \therefore \text{QUALIFIES FOR COMPACT SECTION}$$

COMPRESSION FLANGE TO BE SUPPORTED AT INTERVALS NOT TO EXCEED

$$\frac{76\,b_f}{\sqrt{Fy}} = \frac{76(2.33)}{\sqrt{42}} = 27.3 \text{ (CONTROLS)}$$

NOR

$$\frac{20{,}000}{\left(d/A_f\right)Fy} = \frac{20{,}000}{\left[\frac{3}{(2.33)(.26)}\right]42} = 96.16$$

BRACE DOOR BEAM AT MIDPOINT LATERALLY

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APPENDIX E - CALCULATIONS FOR ENVIRONMENTAL CONDITIONING PENETRATION

CALCULATIONS FOR ENVIRONMENTAL CONDITIONING PENETRATION

For the purposes of this analysis, the Shield Group 81MM has been considered. The procedure is, of course, applicable to all of the shield groups, and is described as follows;

1. Determine the required number of air changes per unit of time, for the particular operation in question. In the absence of specific requirements, we will assume that 2 complete air changes per hour will be provided. This is consistant with industrial practice for places which are not occupied during operations.
2. Calculate the area of the exhaust required to accommodate the required volume of air at a reasonable flow rate.

The area required for the exhaust is given by

$$A_{vent} = \frac{Q}{v}$$

where

A_{vent} = area of the exhaust, $ft.^2$

Q = flow rate, $ft.^3/min.$

v = flow velocity, ft/min.

For a shield volume of 2500 $ft.^3$ and a flow velocity of 400 ft/min (typical for air movement systems), the exhaust area required is

$$A_{vent} = 0.208 \text{ ft.}^2$$

3. Determine the height of the exhaust stack above the building which is required to limit the overpressure on the surrounding structure to an acceptable level. The explosive hazard for the 81MM shield is defined as the simultaneous detonation of three 81MM mortar rounds. This represents a Fano Equivalent of 4.2 lbs of high explosive.

The scaled venting factor is given in Reference 12 as

$$\frac{A}{V^{2/3}}$$

where,

$A = A_{vent}$, $ft.^2$

V = Volume of the space confining explosion, $ft.^3$

For the case in question,

$$\frac{A}{V^{2/3}} = \frac{.208}{(2500)^{2/3}} = .001$$

For the purposes of this analysis, overpressure of 1 psi will be assumed. The designer must select the allowable overpressure on the surrounding building based on the design criterion for the particular application. From Figure 16, for a peak positive pressure (P_{so}) of 1 psi, and a scaled venting factor $\frac{A}{V^{2/3}}$ of .001, the scaled distance, $\frac{R}{W^{1/3}}$ is 7.5.

R = exhaust stack height above the structure, ft.

W = Fano Equivalent = 4.2 lbs. (Ref. 13)

Solving for R,

$$R = 7.5\ W^{1/3} = 7.5\ (4.2)^{1/3} = 12 \text{ ft.}$$

A 12 ft. high stack will be the minimum required.

4. Calculate the required wall thickness of the stack assuming it is circular in cross-section.

   Inside the suppressive shield: The criteria for the portion of the exhaust which is inside the shield is that it have at least the equivalent fragment penetration resistance of the shield itself. For the 81mm shield, this thickness is 1.25 inches.

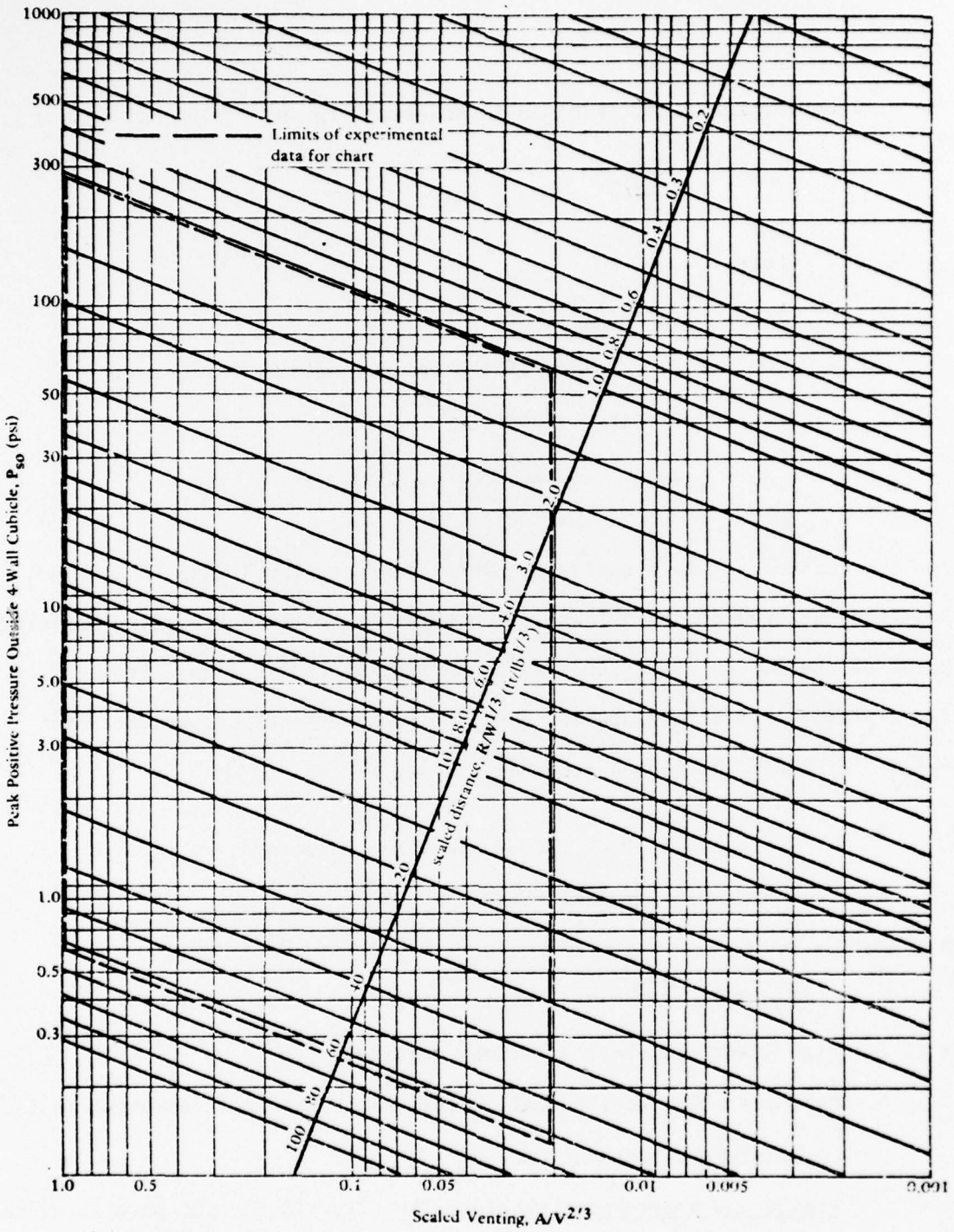

Figure 24 - Design chart for vent area required to limit pressures at any range outside a 4-wall cubicle.

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Outside the suppressive shield: The design criteria in this case is that the stack must withstand the side-on blast pressure caused by the explosion inside the shield.

The scaled distance, Z is given by

$$Z = \frac{R_H}{W\ 1/3}$$

where R_H = the half width of the shield = 7 ft.

W = Fano Equivalent = 4.2 lbs.

Substituting these values,

$$Z = 4.34\ \text{ft/lb.}^{1/3}$$

From Goodman, H. J., 1960, "Compiled Free-Air Blast on Bare Spherical Pentolite" BRL Report No. 1092, APG, Md., the side-on blast pressure, $P_{so} \approx 47.3$ psi for a $Z = 4.34\ \text{ft/lb}^{1/3}$. The hoop stress in a thin round tube subjected to uniform internal pressure is given by:

$$\sigma = \frac{(pr)}{t}$$

where

σ = hoop tension, psi

p = uniform internal pressure, psi = 47.3 psi

r = radius of the tube, in.

t = thickness of the tube, in.

Assuming an allowable stress of = 20,000 psi, the thickness may be expressed as:

$$t = \frac{Pr}{\sigma} = \frac{47.3}{20{,}000}(r) = 2.365 \times 10^{-3}(r)$$

For a stack area of $A_{vent} = .208\ \text{ft.}^2$, the radius, r, is determined by

$$r = \sqrt{\frac{A_{vent}}{\pi}} = \sqrt{\frac{.208}{\pi}} = .26 \text{ ft} = 3.12 \text{ in.}$$

The minimum exterior stack thickness required to withstand the pressure is thus,

$$t = 2.365 \times 10^{-3} \times 3.12 = .007 \text{ in.}$$

Criteria other than pressure from an internal explosion will probably control the design of the stack outside the shield.

APPENDIX F - EXAMPLE MAINTENANCE INSTRUCTION

This appendix presents typical maintenance instructions applicable to the Shield Groups.

DEPARTMENT OF THE ARMY

MAINTENANCE INSTRUCTION

_____

DATE

SUPPRESSIVE SHIELD

SHIELD GROUP ___

_____

NUMBER

PROCEDURE CHANGE NOTICE

PROCEDURE NO.	PCN NO.	PCN INITIATION DATE	PCN COMPLETION DATE	CATEGORY	RESPONSIBLE UNIT	REVISION NO.

PROCEDURE TITLE

SUPPRESSIVE SHIELD GROUP

PROCEDURE TYPE

Preventative Maintenance

AUTHORIZATION

ORIGINATOR	DATE	RESP. UNIT MGR./SUPV	DATE
QA	DATE	TECHNICAL	DATE
SAFETY	DATE	DOCUMENTATION CONTROL	DATE

REASON FOR CHANGE:

REMARKS

		NUMBER _____ REVISION NO. _____ ORIGINATION DATE _____ PAGE 1

1.0 INTRODUCTION

1.1 PURPOSE

This procedure contains the preventative maintenance instructions necessary to ensure the proper operation of the Group __ suppressive shield as listed herein.

1.2 DESCRIPTION

The Suppressive Shields are operational barricades consisting of structural steel and vented composite walls used for containing hazardous munitions plant operations. These shields protect personnel, equipment and facilities against fragments, blast over-pressure, and flame/fireball from accidental explosions and reactions.

1.3 SCOPE

1.3.1 General

The maintenance instructions and operations presented in this document, when performed at the time intervals indicated, provide the basis for periodic preventative maintenance of the suppressive shield.

1.3.2 Maintenance Tasks Included in This Document

The maintenance instruction will be performed in accordance with the requirements of paragraph 7.0 of this procedure. The suppressive shields listed in the Maintenance Performance and Location Check Lists, paragraph 8, will be inspected periodically as follows:

a. Bi-monthly, paragraph 7.1

b. Semi-annual, paragraph 7.2

c. Annual, paragraph 7.3

2.0 REFERENCES

2.1 DOCUMENTS

2.1.1 (To Be Determined)

2.2 DRAWINGS

(List applicable drawings)

2.3 SPECIFICATIONS

(List applicable drawings)

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

(List as required)

3.2 ABBREVIATIONS

(List as required)

4.0 RESPONSIBILITIES

a. Personnel assigned to perform these maintenance instructions shall be responsible for the safety of personnel and equipment, and will be responsible for following this procedure as outlined herein.

b. Minor adjustments will be accomplished at time of inspection.

c. Rework requiring parts, special effort (in addition to routine), and fabrication shall be documented by the performing organization for corrective action. These reports will be forwarded to the work control center for scheduling and implementation of the corrective maintenance.

5.0 SUPPORT REQUIREMENTS

5.1 SPECIAL TOOLS/TEST EQUIPMENT

a. Resistance measuring device (approved instrument)

b. Test leads, clips, and surface plates

c. Optical transit

5.2 EQUIPMENT

a. Standard hand tools

b. Ladder

5.3 MATERIAL

a. Safety approved dry graphite lubricant or equivalent

b. Safety approved solvent, as required

c. Shop rags

6.0 PREREQUISITES

6.1 EQUIPMENT CONFIGURATION

Normal

6.2 FUNCTIONAL PREREQUISITES

a. Advise user of inspection. Determine occupancy and operational status of shield and observe posted regulations in respective area.

b. Follow standard lock-and-tag procedure and secure for inspection per Safety Manual Regulations.

c. Advise user when inspection is complete and restored to normal. Discuss with user if unusual or unsatisfactory service conditions have been experienced.

		NUMBER _____ REVISION NO. _____ ORIGINATION DATE _____ PAGE 4

NOTE: OBSERVE AND COMPLY WITH ALL PLANT AND AREA WARNING SIGNS AND REGULATIONS

7.0 PROCEDURE

Refer to paragraphs 1.0 through 6.0 prior to performing this procedure.

7.1 BI-MONTHLY MAINTENANCE TASKS

7.1.1 Perform a complete visual inspection of the Suppressive Shield, checking for interior and exterior surfaces.

a. Worn areas, punctures, cuts, and cracks of the environmental covering of all interior and exterior surfaces.

b. Cracks and spalling of the concrete surfaces of the roof and foundation slab.

c. Presence of rust, blistering, or peeling paint.

d. Condition of conductive floor material.

e. Condition of electrical ground straps, lightning rods and cables.

f. Evidence of processed material accumulation on interior surfaces.

g. Condition of service penetrations.

h. Condition of interior lighting devices.

i. Condition of expansion joint calking around foundation.

7.1.2 Clean shield and equipment with appropriate solvent and shop rags.

7.1.3 Functionally check operation of personnel and process equipment doors.

7.1.4 Check operation of all switches, interlocks, and indicator lamps. (Replace lamps as required.)

7.1.5 Lubricate moving parts as required.

7.2 SEMI-ANNUAL MAINTENANCE TASKS

7.2.1 Check tightness of structural bolts as required.

7.2.2 Check tightness of ground strap bolts.

7.3 ANNUAL MAINTENANCE TASKS

7.3.1 Perform tests for proper electrical resistance and continuity to ground in accordance with USAMC Regulations 385-100, for the following:

a. Static grounds (equipment)

b. Conductive floors

c. Lightning protection system.

7.3.2 Perform check for foundation settling of the shielding structure by setting up and sighting the optical transit from pre-established reference points to targets scribed on the exterior shield walls in accordance with detailed Plant Operating Procedures. (Number to be provided).

8.0 SUPPLEMENTARY DATA

8.1 Sample check list for each applicable location and maintenance period follows.

MAINTENANCE PERFORMANCE AND LOCATION CHECK LIST

PROCEDURE TITLE	PROCEDURE NO.	LOCATION	DATE PERFORMED	MAINT. FREQ. Annual

PARAGRAPH NO.	7.3.1.a		7.3.1.b		7.3.1.c		7.3.2																				VERIFICATION SIGNATURES
CONDITION →	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	
LOCATION																													

MAINTENANCE PERFORMANCE AND LOCATION CHECK LIST

PROCEDURE TITLE	PROCEDURE NO.	LOCATION	DATE PERFORMED	MAINT. FREQ. Semi-Annual

PARAGRAPH NO.	7.2.1		7.2.2																									
CONDITION ⟶	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U
LOCATION																												

MAINTENANCE PERFORMANCE AND LOCATION CHECK LIST

PROCEDURE TITLE	PROCEDURE NO.	LOCATION	DATE PERFORMED	MAINT. FREQ. Bi-Monthly

PARAGRAPH NO.	7.1.1.a	7.1.1.b	7.1.1.c	7.1.1.d	7.1.1.e	7.1.1.f	7.1.1.g	7.1.1.h	7.1.1.i	7.1.2	7.1.3	7.1.4	
CONDITION ——→	S U	S U	S U	S U	S U	S U	S U	S U	S U	S U	S U	S U	VERIFICATION SIGNATURES
LOCATION													

PROCEDURE NUMBER _____
REVISION NUMBER _____
ORIGINATION DATE _____
PAGE ____ CONT'D ON PAGE ____

CODES	REMARKS
S - Satisfactory . U - Unsatisfactory	

APPENDIX G - WELDING PROCEDURE AND QUALIFICATION

This appendix presents an example of a welding procedure which shall be required for the fabrication of the shield penetrations and openings as well as for the basic shield structure. The AWS Structural Welding Code, AWS D1.1-75, is specified for the welding. The quality control and inspection procedures will vary depending upon the critical nature of the weld but AWS1.1-75 contains the required provisions in Section 6 - Inspection.

The following example only illustrates what a welding procedure would consist of and is not meant to be all encompassing. Each situation will require perhaps a slightly different procedure but by specifying the submission of a welding procedure from the shield fabricator, the structural integrity of the shield can be insured.

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2.0	Processes	G-3
3.0	Positions	G-3
4.0	Joint Design	G-3
5.0	Heat Control	G-3
6.0	Electrodes	G-3
7.0	Preparation of Base Metals	G-4
8.0	Joint Welding	G-4
9.0	Repairs	G-4
10.0	Qualification of Welders	G-4
11.0	Base Metals	G-5

Appendix: Prequalified Joint Welding Procedure
Welder Qualification Test Results

WELDING PROCEDURE

Note: Local regulations and SOP's regarding flame permits prior to welding must be followed. Decontamination of the shield shall be in accordance with the local AAP SOP's, AMCR 385-100 (Safety Manual) and ARMCOM Regulation 385-5 (Contamination, Decontamination, and Disposal).

1.0 APPLICABILITY

All welding shall be performed in accordance with the AWS Structural Welding Code AWS D1.1-75.

2.0 PROCESSES

2.1 Manual Shielded Metal Arc Process (SMAW)

2.2 Gas Shielded Metal Arc Process (GMAW)

2.3 Gas Shielded Tungsten Arc Process (GTAW)

3.0 POSITIONS

Positions which may be used include flat, vertical, and horizontal.

4.0 JOINT DESIGN

All joints are to be as shown on applicable drawings and are prequalified in accordance with AWS D1.1-75.

5.0 HEAT CONTROL

5.1 Any required field preheating to be done with a torch.

5.2 Preheat values and interpass temperatures are to be determined from Table 4.2 of AWS D1. 1-75.

6.0 ELECTRODES

6.1 The manual shielded metal arc process shall use low hydrogen electrodes of the E7018 type in accordance with AWS A5.1.

6.2 The inert gas shielded arc processes shall use wires of the MIL-E70S type which conform to AWS A5.18.

6.3 Electrodes used for the SMAW process shall arrive at the site in hermetically sealed containers. After opening, the electrodes shall immediately be placed in ovens held at 250°F minimum. After removal from holding ovens, those not used within four hours shall be redried before use according to paragraph 4.9.2 of AWS D1.1-75.

7.0 PREPARATION OF BASE METALS

7.1 Edges may be machined, sawed, ground or flame cut. Flame cut edges need not be ground if smooth, free of gouges, scale and slag.

7.2 Prior to fitting, the surfaces of the joints to be welded shall be cleaned of loose scale or other foreign matter for a distance of one-half inch beyond the extremity of welds.

8.0 JOINT WELDING

8.1 Weld layer thickness should not exceed 5/16". Each weld layer shall be started at the end of the finishing end of the preceeding layer, except where procedure must be varied to eliminate distortion.

8.2 Weld passes are to be cleaned of all slag or other foreign matter before deposition of additional passes.

8.3 Arc starts and stops are to be chipped or ground as necessary ton insure sound welding.

8.4 Excessive slag and splatter are to be removed from finished welds.

8.5 Undercut at the edges of finished welds shall be held to a minimum but not exceed .030" or 10% of thinner members, whichever is less, for more than 5% of the length of any given weld surface.

8.6 On completion of welding, the finished joints shall be allowed to cool to room temperature. Mechanical means of cooling shall not be allowed.

9.0 REPAIRS

9.1 Excavation of defects may be made by chipping or grinding. The excavated areas shall be beveled in accordance with joint requirements.

9.2 All repairs are to be made with the same type electrodes as the original welds.

9.3 Inspection of repaired areas shall be in accordance with original requirements.

10.0 QUALIFICATION OF WELDERS

Welders qualified in accordance with Section 5 of AWS D1.1 or with MIL-STD-248 shall be used.

11.0 BASE METALS

11.1 Steel plates, shapes, and bars shall conform to ASTM-A36.

11.2 Steel tubing shall conform to ASTM-A501.

PREQUALIFIED JOINT WELDING PROCEDURE
PROCEDURE SPECIFICATION

Material specification.....
Welding process.....
Manual or machine.....
Position of welding.....
Filler metal specification.....
Filler metal classification.....
Flux.....
Weld metal grade.....
Shielding gas..... Flow.....
Single or multiple pass.....
Single or multiple arc.....
Welding current.....
Polarity.....
Welding progression.....
Root treatment.....
Preheat and interpass temperature.....
Postheat treatment.....

WELDING PROCEDURE

Pass no.	Electrode size	Welding Current		Travel speed	Joint Detail
		Amperes	Volts		

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the limitation of variables given in 4B, C, or D AWS D1.1, Structural Welding Code.

Manufacturer or Contractor.....

Authorized by.....

Date.....

WELDER AND WELDING OPERATOR QUALIFICATION TEST RECORD

Welder or welding operator's name ..... Identification no. .....
Welding process ..... Manual ..... Semiautomatic ..... Machine .....
Position .....
(Flat, horizontal, overhead or vertical – if vertical state whether upward or downward)
In accordance with Procedure Specification No. .....
Material specification .....
Diameter and wall thickness (if pipe) otherwise joint thickness .....
Thickness range this qualifies .....

FILLER METAL

Specification No. ..... Classification ..... F No. .....
Describe filler metal (if not covered by AWS specification) .....
.....
Is backing strip used? .....

Filler metal diameter and trade name ..... Flux for submerged arc or gas for gas metal arc or flux
..... cored arc welding .....

Guided Bend Test Results

Type	Result	Type	Result

Test conducted by..... Laboratory Test No. .....
per.....

RADIOGRAPHIC TEST RESULTS

Film Identification	Results	Remarks	Film Identification	Results	Remarks

Test witnessed by_____ Test no._____
per_____

We the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of 5C or D of AWS D1.1, Structural Welding Code.

Manufacturer or Contractor .....

Authorized by .....

Date .....

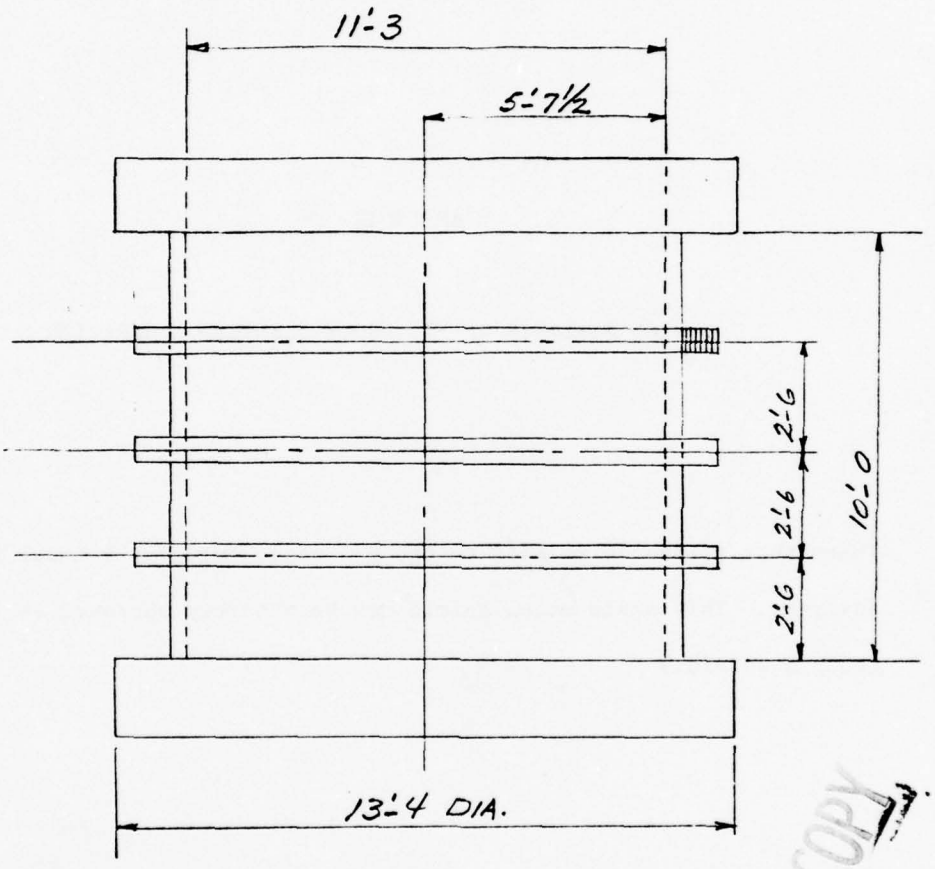
APPENDIX H

DESIGN ANALYSIS OF THE GROUP 3 SHIELD FOUNDATION

(Note that reference is made to the 1/4 scale category 1 model in the analysis. This scale model shield has been safety approved as the group 3 shield.)

U. S. ARMY
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY:	DATE:
SUPPRESSIVE SHIELD DESIGN CATEGORY I 1/4 SCALE MODEL	E. WILLIAMS CHECKED BY: R.M.H.	DATE:



DESIGN STRESSES

CONCRETE
$f'_{dc} = 1.25 \times 5000 = 6250$ Psi
$f'_{d\,Shear} = 5000$ Psi

REINFORCING
$f_{dy\,BENDING} = 1.10 \times 60{,}000 = 66{,}000$ Psi
$f_{dy\,SHEAR} = 60{,}000$ Psi

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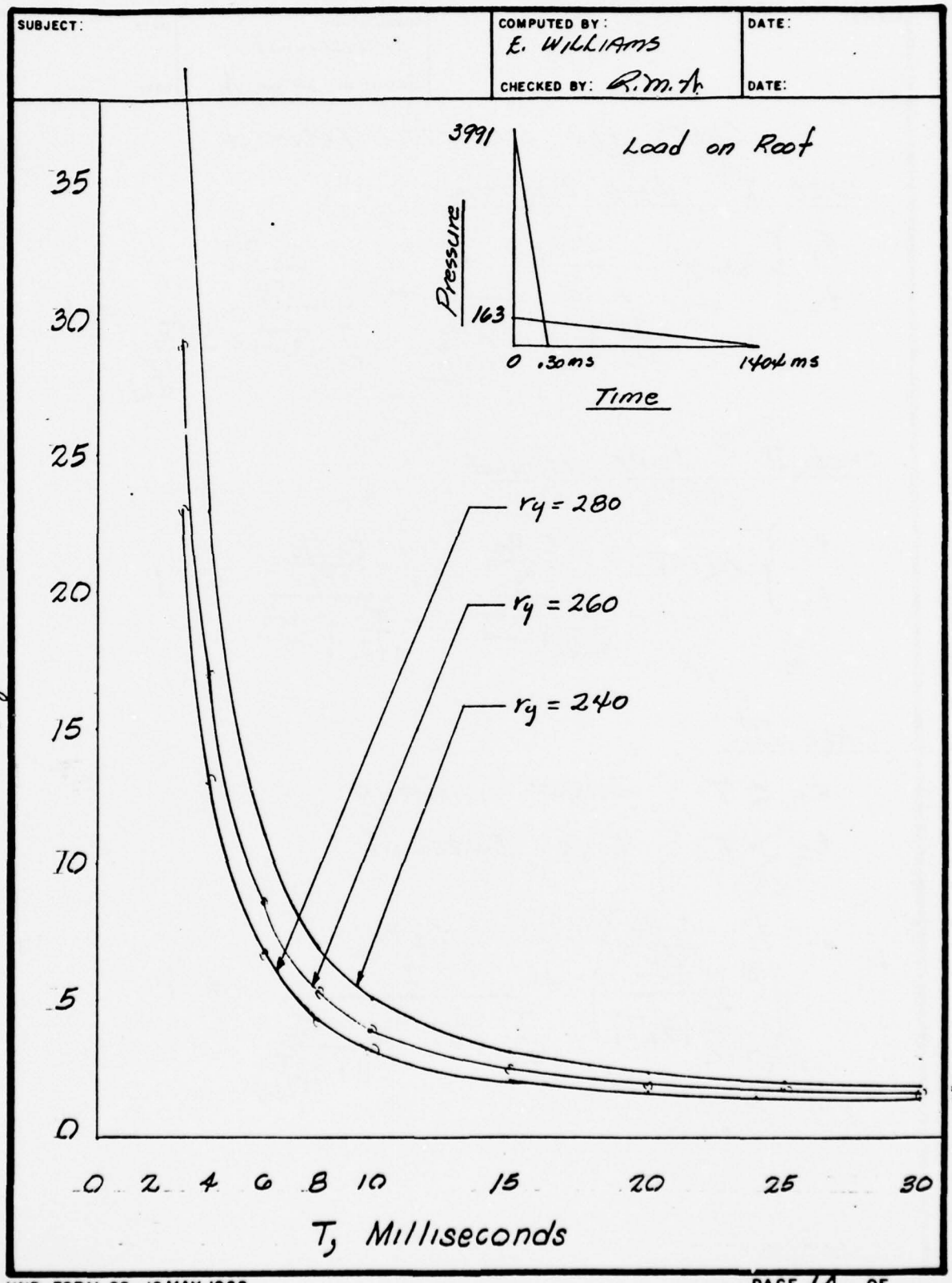
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.A.	DATE: DATE:



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SUBJECT:	COMPUTED BY: E. Williams	DATE:
	CHECKED BY: R. M. A.	DATE:

CASES FOR STRUCTURAL RESPONSE

CASE I LONG DURATION

$$\left.\begin{matrix} t_1 \\ t_2 \end{matrix}\right\} >> T \qquad \frac{\frac{C_1 P_m}{r_y}}{\frac{T}{\pi t_{d_1}}\sqrt{2\mu-1} + \frac{1-\frac{1}{2\mu}}{1+.7\left(\frac{T}{t_{d_1}}\right)}} + \frac{\frac{C_2 P_m}{r_y}}{\frac{T}{\pi t_{d_2}}\sqrt{2\mu-1} + \frac{1-\frac{1}{2\mu}}{1+.7\left(\frac{T}{t_{d_2}}\right)}} = 1$$

CASE II PURE IMPULSE

$$\left.\begin{matrix} t_1 \\ t_2 \end{matrix}\right\} << T \qquad \frac{\frac{C_1 P_m}{r_y}}{\frac{T}{\pi t_{d_1}}\sqrt{2\mu-1}} + \frac{\frac{C_2 P_m}{r_y}}{\frac{T}{\pi t_{d_2}}\sqrt{2\mu-1}} = 1$$

CASE III

$t_1 < T$ SHORT DURATION

$t_2 > T$ LONG DURATION

$$\left(\frac{\frac{C_1 P_m}{r_y}}{\frac{T}{\pi t_{d_1}}\sqrt{2\mu-1}}\right)^2 + \frac{\frac{C_2 P_m}{r_y}}{\frac{T}{\pi t_{d_2}}\sqrt{2\mu-1} + \frac{1-\frac{1}{2\mu}}{1+.7\left(\frac{T}{t_{d_2}}\right)}} = 1$$

U. S. ARMY
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.M.	DATE:

ESTIMATE DESIGN PRESSURE
FOR CONCRETE ROOF & FOUNDATION

ASSUME TM 5-1300 TYPE I CONSTRUCTION

$\theta = 2°$ $\quad X_m = \tan 2° (67.5") = 2.36"$

$$\mu = \frac{X_m}{X_y} = \frac{2.36}{.236 \text{ EST.}} = 10$$

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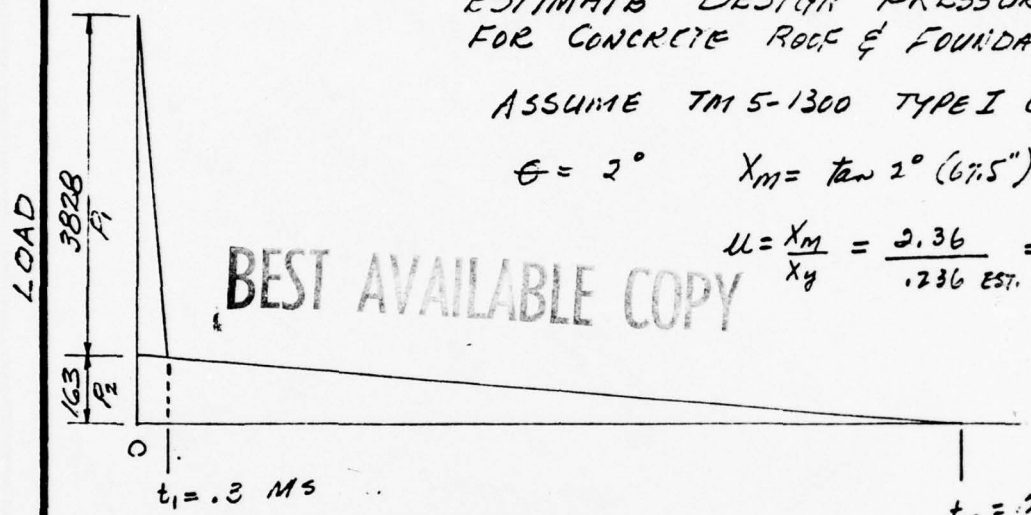

CASE III

$$c_1 = \frac{3828}{3991} = .9592$$

$$c_2 = \frac{163}{3991} = .0408$$

ASSUME $\mu = 10$
" $T = 11$ MS

$$\left(\frac{\frac{C_1 P_m}{r_y}}{\frac{T}{\pi t_{d_1}}\sqrt{2\mu-1}}\right)^2 + \frac{\frac{C_2 P_m}{r_y}}{\frac{T}{\pi t_{d_2}}\sqrt{2\mu-1} + \frac{1-\frac{1}{2\mu}}{1+.7\left(\frac{T}{t_{d_2}}\right)}} = \left(\frac{\frac{3828}{r_y}}{\frac{11}{\pi(.3)}\sqrt{2(10)-1}}\right)^2 + \frac{\frac{163}{r_y}}{\frac{11}{\pi(1404)}\sqrt{2(10)-1} + \frac{1-\frac{1}{2(10)}}{1+.7\left(\frac{11}{1404}\right)}} = 1$$

$$\left(\frac{\frac{3828}{r_y}}{50.87}\right)^2 + \frac{\frac{163}{r_y}}{.9557} = \left(\frac{75.254}{r_y}\right)^2 + \frac{170.38}{r_y} = \frac{5663.16}{r_y^2} + \frac{170.38}{r_y} = 1$$

$$\frac{5663.16 + 170.38 r_y}{r_y^2} = 1 \qquad r_y^2 - 170.38 r_y + \left(\frac{170.38}{2}\right)^2 = 5663.16 + \left(\frac{170.38}{2}\right)^2$$

$$(r_y - 85.19)^2 = 5663.16 + 7257.34$$

$$r_y - 85.19 = \sqrt{12,920.50} = 113.67$$

$$r_y = 113.67 + 85.19 = 198.86$$

FOR DESIGN USE $r_y = 250$ PSI

U. S. ARMY
HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: RMH	DATE:

USE A 1/4 SEGMENT FOR DESIGN
PROPERTIES OF A 1/4 SEGMENT

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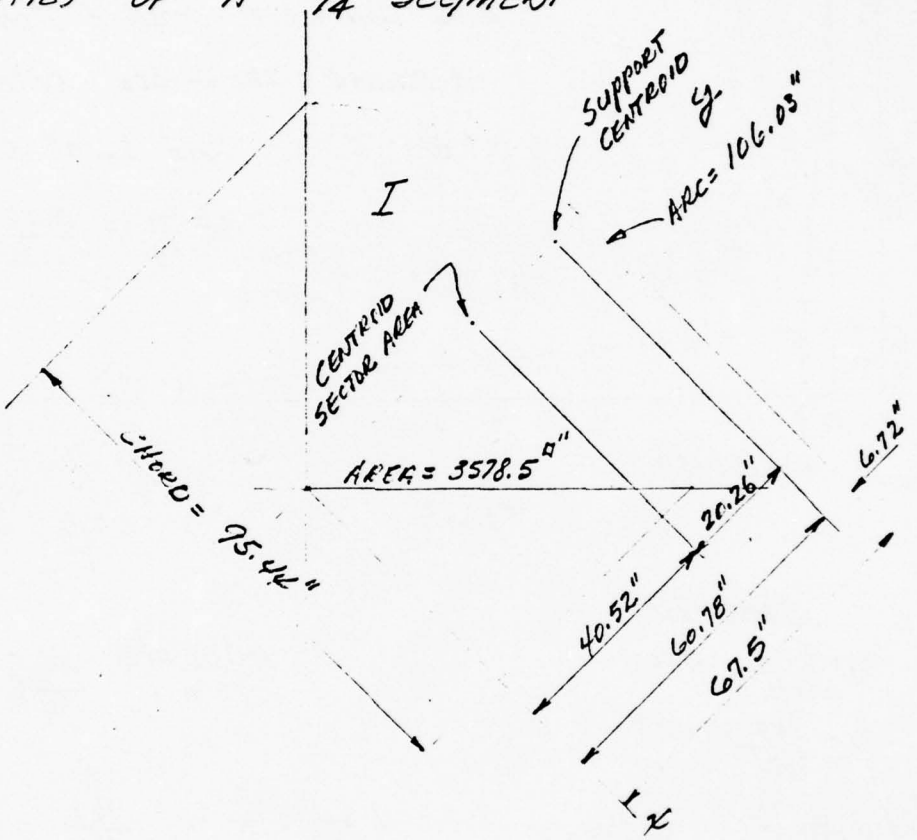


ARC OF SEMICIRCLE

$$\bar{y} = \frac{2R}{\pi(.707)} = \frac{2(67.5)}{\pi(.707)} = 60.78$$

AREA OF SEMICIRCLE

$$\bar{y} = \frac{4R}{3\pi(.707)} = \frac{4(67.5)}{3(\pi)(.707)} = 40.52$$

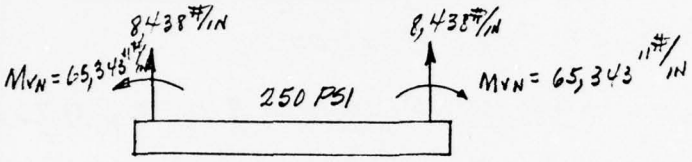
LENGTH OF ARC $= \frac{\pi D}{4} = \frac{\pi(135)}{4} = 106.03"$

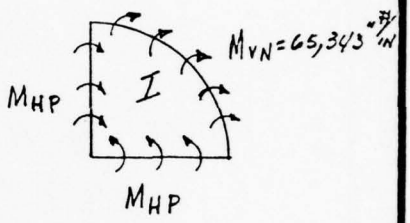
AREA $= \frac{\pi d^2}{4(4)} = \frac{\pi(135)^2}{16} = 3578.5\ \square"$

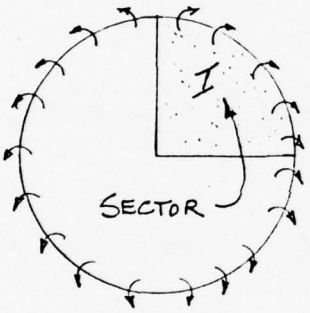
CHORD $= 1.414\,R = 1.414(67.5) = 95.44"$

SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.th	DATE:

DETERMINE MOM. M_{HP} ON YIELD LINE







FOUNDATION & ROOF SLAB

TOTAL AXIAL LOAD = $\frac{\pi d^2}{4}(P) = \frac{\pi(135)^2}{4}(250) = 3,578,470^{\#}$

LOAD PER INCH = $\frac{3,578,470}{\pi(135)} = 8,438^{\#}/IN$

PREVIOUS CAL. M/BM

$M_{VN} = \frac{5,150^{\#}}{1.433}\left(\frac{250}{165}\right)12 = 65,343^{"\#}/IN$

BM SPACING

USING EQ 5-23 TM 5-1300

$\Sigma M_N + \Sigma M_P = r_u A C$

$r_u = 250^{\#}/\square"$, $A = 3578.5$, $C = 20.26"$

$\Sigma M_{VN} = \frac{\overset{32,671.5}{65,343}}{2} \times 95.44 = 3,118,168^{"\#}$

$\Sigma M_{HP} = 95.44\ M_{HP}$

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$\Sigma M_{VN} + \Sigma M_{HP} = r_u A C$

$3,118,168 + 95.44 M_{HP} = 250 (3578.5)(20.26)$

$M_{HP} = \dfrac{250(3578.5)(20.26) - 3,118,168}{95.44} = 157,240$ #

USING Eq. 16 P 29 RH. Wood

$r_u R^2 = 6 (M_{HP} + M_{VN})$

$M_{HP} = \dfrac{r_u R^2 - 6 M_{VN}}{6} = \dfrac{250 (67.5)^2 - 6 (32,671.5)}{6} = 157,172$ #

DETERMINE SLAB THICKNESS TM 5-1300 TYPE I SECTION

$P_b = \dfrac{0.85 K_1 f'_{dc}}{f_{dy}} \left(\dfrac{87,000}{87,000 + f_{dy}} \right) = \dfrac{0.85(0.80)(6250)}{66,000} \left(\dfrac{87,000}{87,000 + 66000} \right)$

$P_b = .0366$

$.75 P_b = 0.75 \times 0.0366 = 0.027$ USE 2%

$m = \dfrac{f_{dy}}{.85 f'_{dc}} = \dfrac{66,000}{.85(6250)} = 12.42$ REF. RCD by WANG & SALMON PG. 46

$R_u = p f_{dy} \left(1 - \dfrac{pm}{2} \right) = .02 (60000) \left[1 - \dfrac{(.02)(12.42)}{2} \right] = 1156$

$bd^2 = \dfrac{M_{HP}}{K_u}$ $\quad d^2 = \dfrac{157,240}{1(1156)} = 136.02$

$d = \sqrt{136.02} = 11.66$"

SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.H.	DATE: DATE:

CHECK FOR DIAGONAL TENSION & DIRECT SHEAR

$$V_{SV} = \frac{V_u A}{A_{VC}} = \frac{250(3578.5)}{106.03} = 8437.5\ ^{\#}/_{IN}$$

$$v = 10\phi\sqrt{f'_c} = 10(.85)\sqrt{5000} = 601\ ^{\#}/_{\square"}$$

$$v_u = \frac{V_u}{bd} \qquad d = \frac{8437.5}{601(1)} = 14.04" \quad \text{CONTROLS}$$

$$V_d = 0.18 f'_c\, bd \qquad d = \frac{V_u}{.18 f'_c\, b} = \frac{8437.5}{.18(5000)1} = 9.4"$$

USE $d = 16$
$T_c = 18$

DETERMINE REBAR SIZE & SPACING

$$\text{REQ'D } K_u = \frac{M_{HP}}{bd^2} = \frac{157,240}{(1)(16)^2} = 614.22\ ^{\#}/_{\square"}$$

$$p = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mK_u}{f_{dy}}}\right)$$

$$p = \frac{1}{12.42}\left(1 - \sqrt{1 - \frac{2(12.42)(614.22)}{66,000}}\right) = .00992$$

$$A_S = p\,bd = .00992(12)(16) = 1.90\ ^{\square"}/_{FT}$$

USE 2 LAYERS ONE SIDE ONLY
$\frac{1}{2} \times 1.7664 = .8832$

#3 @ $1\frac{3}{8}$" $A_S = .96\ ^{\square"}$

OR #4 @* $2\frac{1}{2}$" $A_S = .96\ ^{\square"}$

* SPACING CHANGED TO 2½" DUE TO OTHER CONSIDERATIONS (SH. 13)

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SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.W.	DATE: DATE:

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CHECK MOMENT CAPACITY (MHP)

$$p = \frac{A_s}{bd} = \frac{(.96)2}{12(16)} = .01$$

$$a = \frac{A_s f_{dy}}{.85 b f'_{dc}} = \frac{1.92(66,000)}{.85(12)(6250)} = 1.99"$$

$$M_{PROVIDED} = A_s f_{dy} \left(d - \frac{a}{2}\right)$$

$$M = 2(.96)^{\#/\square"}(66,000)^{\#/\square"}\left[16" - \frac{1.99}{2}\right] = 1,901,575" \#/FT$$

OR $158,465"\#/" > 157,240"\#$

OK

CHECK MOM. CAPACITY @ SUPPORT (M_{VN}) USING ONE LAYER

$$a = \frac{A_s f_{dy}}{.85 b f'_{dc}} = \frac{.96(66,000)}{.85(12)(6250)} = .994$$

$$M_{PROVIDED} = A_s f_{dy}\left(d - \frac{a}{2}\right)$$

$$= .96(66,000)\left(16.75 - \frac{.994}{2}\right)$$

$$= 1,061,280"\#/FT \text{ OR } 88,440"\#/" > 65,343"\#/"$$

SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.A.	DATE:

DESIGN STIRRUPS

SHEAR PERMITTED ON CONCRETE

$V_c = \phi\left[1.9\sqrt{f'c} + 2500p\right]$

$= .85\left[1.9\sqrt{5000} + 2500(.01)\right]$

$= 135$ Psi (USE THIS)

$V_{c_{MAX}} = 2.28\phi\sqrt{f'c}$

$= 2.28(.85)\sqrt{5000}$

$= 137$ Psi

USE BRITTLE FAILURE MODE $\mu = 1.5$ FOR PURE SHEAR ONLY

MAXIMUM $V_u = 10\phi\sqrt{f'c} = 10(.85)\sqrt{5000} = 601$ PSI

MAXIMUM SPACING ON STIRRUPS $= \frac{d}{4} = \frac{16}{4} = 4$

$\mu = 1.5$ FOR BRITTLE MODE

$$\left(\frac{\frac{C_1 P_M}{r_y}}{F_1}\right)^2 + \frac{\frac{C_2 P_M}{r_y}}{F_2} = 1$$

$$\left(\frac{3828}{16.5\, r_y}\right)^2 + \frac{163}{.6667\, r_y} = 1$$

$$\frac{53828.78}{r_y^2} + \frac{244.23}{r_y} = 1$$

$$\frac{53828.78 + 244.23\, r_y}{r_y^2} = 1$$

$$r_y^2 - 244.23\, r_y + \left(\frac{244.23}{2}\right)^2 = 53828.78 + \left(\frac{244.23}{2}\right)^2$$

$$(r_y - 122.12)^2 = 53828.78 + 14912.41$$

$$r_y - 122.12 = \sqrt{68741.19}$$

$$r_y = 262.18 + 122.12 = 384.21$$

$F_1 = \frac{I}{\pi t d_1}\sqrt{2\mu - 1}$

$F_1 = \frac{11}{\pi(.3)}\sqrt{2(1.5) - 1}$

$F_1 = 16.5$

$F_2 = \frac{I}{\pi t d_2}\sqrt{2\mu - 1} + \frac{1 - \frac{1}{2\mu}}{1 + .7\left(\frac{I}{td}\right)}$

$F_2 = \frac{11}{\pi(.204)}\sqrt{2(1.5) - 1} + \frac{1 - \frac{1}{2(1.5)}}{1 + .7\left(\frac{11}{16.4}\right)}$

$F_2 = .6667$

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HUNTSVILLE DIVISION, CORPS OF ENGINEERS

SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.H.	DATE: DATE:

$V = \frac{384.31(3578.5)}{106.13} = 12,970\ \#/IN$

RECHECK d $\quad d = \frac{V_u}{.18(1.1)(5000)} = \frac{12,970}{.18(1.1)(5000)} = 13.1 < 16$ OK

DESIGN STIRRUPS FOR DUCTILE FAILURE MODE

$V = \frac{250(3578.5)}{106.13} = 8437.5\ \#/IN \qquad v_u = \frac{8437.5}{16} = 527\ PSI$

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SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.H.	DATE:

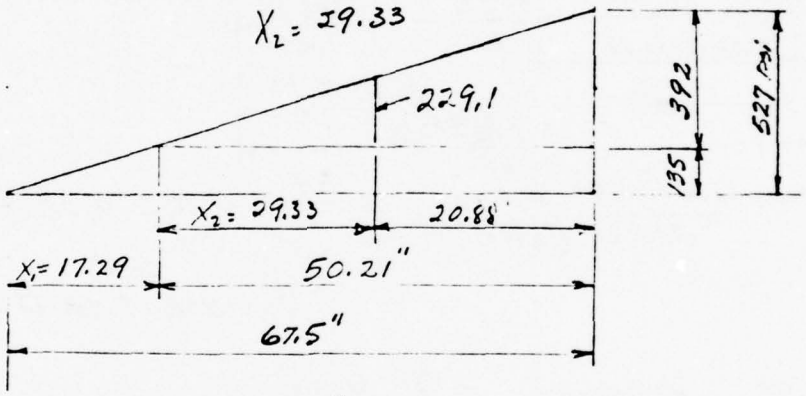
CRITICAL SECTION AT ANCHOR BOLT

$\frac{V_1}{135} = \frac{67.5}{527}$

$V_1 = 17.29"$

$\frac{229}{X_2} = \frac{392}{50.21}$

$X_2 = 29.33$



SHEAR ON 3" STRIP

TRY 1/4" ϕ STIRRUPS $A = .049"$

$S_S = \frac{\phi A_s f_s}{(V_u - V_c) b_s} = \frac{.85(.049)(66,000)}{392(3)} = 2.33"$ USE $2\frac{1}{2}$

No. STIRRUPS $= \frac{392(50.21)(3)}{2(.0491)(66,000)} = 9$

DETERMINE STRESS AT 4" SPACING

$V_{@4} = \frac{.85(.049)(66,000)}{4(3)} = 229.1$ PSI

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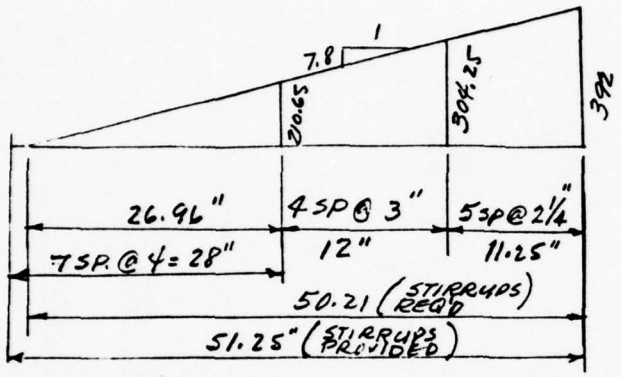
SUBJECT:	COMPUTED BY: E. Williams	DATE:
	CHECKED BY: R.M.H.	DATE:



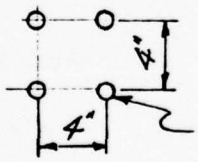
$$S_S = \frac{.85(.049)(66{,}000)}{304.25\,(3)} = 3^{+}$$

USE 4 SP. @ 3" = 12"

USE 7 SP. @ 4" = 28"

% OF STEEL

CONSIDER 1/4 OF EACH BAR CONTRIBUTING TO A 4" X 4" AREA



$$P_V = \frac{.049}{16} = .003 > .0025 \therefore \text{IT IS DUCTILE MODE}$$

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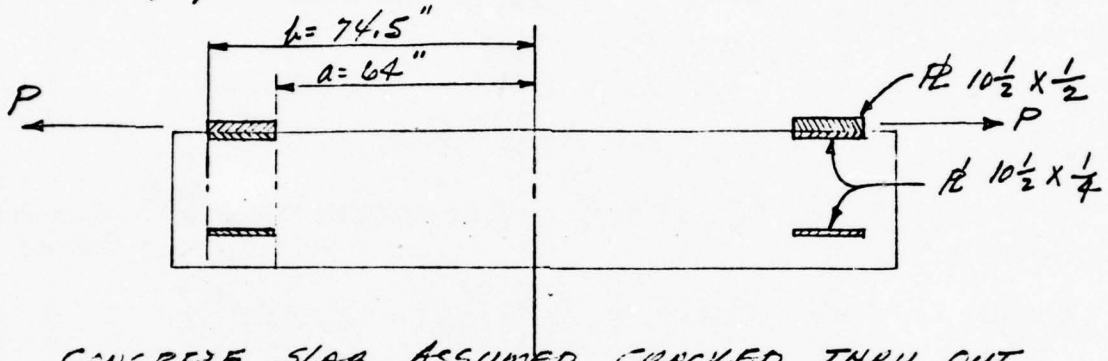
SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R. Smith.	DATE: DATE:

DETERMINE RADIAL TENSILE STRESS ON BASE ℄ RING & REBARS



CONCRETE SLAB ASSUMED CRACKED THRU OUT TAKE NO TENSION.

$$P = \frac{5{,}460\left(\frac{250}{165}\right)(296)}{\pi \times 135} = 5774\ \#/IN$$

$$U_{BAR} = \frac{PL}{AE_s} = \frac{P_b L}{E_s} = \frac{P_b(26)}{E_s} = \frac{2P_b b}{E_s} = \frac{2(74.5)P_b}{29\times10^6} = 5.14\times10^{-6}P_b$$

$$U_{RING\ ℄} = \frac{bP_r}{E_s}\left(\frac{a^2+b^2}{b^2-a^2} - \mu\right)$$

P_b = STRESS ON REBAR
P_r = RADIAL STRESS ON RING

TIMOSHENKO STRENGTH OF MAT. PART II, PG 210

$$= \frac{74.5P_r}{29\times10^6}\left[\frac{(64)^2+(74.5)^2}{(74.5)^2-(64)^2} - 0.30\right] = 1.627\times10^{-6}P_r$$

$$U_B = U_R = 5.14\times10^{-6}P_b = 1.627\times10^{-6}P_r$$

$$P_b = \frac{1.627\times10^{-6}}{5.14\times10^{-6}}P_r = .316P_r$$

$$A_b P_b + P_r = P$$

USING # 4 @ 2½" SPACING

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SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: RMith	DATE: DATE:

$A_b P_b + P_r = P$

$3(.20)\left(\frac{1}{2.5}\right)(.316 P_r) + P_r = 5774\ ^{\#}/_{IN}$

$.076 P_r + P_r = 5774$

$1.076 P_r = 5774$

$P_r = 5367\ ^{\#}/_{\square''}$

$P_b = .316 P_r = .316(5367) = 1696\ ^{\#}/_{''}$ LOAD ON REBARS

LOAD /FT ON REBARS $= 1696(12) = 20352\ ^{\#}/_{FT}$

AREA REQ'D $= \frac{20,352}{66,000} = .31\ ^{\square''}$

#4 @ 2½ ONE LAYER ON TOP

$P = \frac{.96}{12(16)} = .005$ PROVIDED

TOP STEEL REQ'D FOR BENDING

$K_u = \frac{M}{bd^2} = \frac{65,343(12)}{12(16)^2} = 255$

REQ'D $p = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m K_u}{f_{dy}}}\right]$

$p = \frac{1}{12.42}\left[1 - \sqrt{1 - \frac{2(12.42)(255)}{66,000}}\right]$

$p = .00396$

AVAIL. TOP STEEL RATIO FOR AXIAL LOAD $= .005 - .00396 = .00104$

#4 @ 2½ TWO LAYERS ON BOTTOM

$p = \frac{2(.96)}{12(16)} = .01$ PROVIDED

SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: RMM	DATE: DATE:

AVAIL. BOTTOM STEEL RATIO = .01 − .00992 = .00108

TOTAL AVAIL. STEEL TOP & BOT = .00104 + .00008 = .00112

TOTAL AREA OF STEEL FOR AXIAL LOAD = .00112(12)(16) = .2150 $\square''$
< .31 $\square''$
N.G.

DECREASE SPACING OF TOP & BOTTOM REINFORCING

TRY 2¼ SPACING

4 @ 2¼ = 1.07 $\square''$/FT

$$p = \frac{1.07}{12(16)} = .00557\ \square''$$ PROVIDED AT TOP

$$p = \frac{2(1.07)}{12(16)} = .01115\ \square''$$ PROVIDED AT BOT.

AVAIL. @ TOP = .00557 − .00396 = .00161 $\square''$

AVAIL. @ BOT. = .01115 − .00992 = .00123 $\square''$

TOTAL = .00284 $\square''$

TOTAL AREA AVAIL. FOR AXIAL LOAD = .00284(12)(16) = .54 $\square''$ > .31 $\square''$
OK.

SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.H	DATE: DATE:

COMPUTE ELASTIC STATIC DEFLECTION, X_e

ROARK TABLE X PAGE 216

$E_c = W^{1.5} 33\sqrt{f'c} = (150)^{1.5} 33\sqrt{5000} = 4.29 \times 10^6$

$\nu = 0.15$

$m = \frac{1}{\nu} = \frac{1}{0.15} = 6.67$

$$y_{ss} = \frac{3W(m-1)(5m+1)a^2}{16\pi E m^2 t^3}$$

$$= \frac{(3)\frac{\pi}{4}(135)^2(250)(6.67-1)[5(6.67)+1](67.5)^2}{16\pi(4.29)(10^6)(6.67)^2(18)^3}$$

$y_{ss} = .17"$ SIMPLE SUPPORTED

$$y_F = \frac{3W(m^2-1)a^2}{16\pi E m^2 t^3}$$

$$= \frac{3\frac{\pi}{4}(135)^2(250)\left[6.67^2-1\right](67.5)^2}{16\pi(4.29)(10^6)(6.67)^2(18)^3}$$

$= .038"$ FIXED

DETERMINE NATURAL FREQUENCY OF SLAB

AFDM 8-27 $T = 5.3\sqrt{\frac{W}{Kg}}$ FOR SQUARE SLAB W/SIMPLE SUPPORTS

$$\frac{W}{g} = \frac{(150\ lb/FT^3)(18\ IN)}{(32.2\ FT/SEC^2)(12\ IN/FT)(1728\ IN^3/FT^3)} = .00404$$

$K = \frac{252\ E_c I_a}{L^4}$

$K = \frac{252(4.29)(10^6)(330.04)}{(135)^4}$

$k = 1074.2$

$T = 5.3\sqrt{\frac{.00404}{1074.2}} = .0103$

$f_n = \frac{1}{T} = 97.3$ CPS

$f_{n_2} = 97.3\left(\frac{5.90}{5.70}\right) = 100.7$

$I_a = \frac{I_c + I_g}{2}$

$I_a = \frac{174.08 + 486}{2}$

$I_a = 330.04$

$I_c = Fbd^3$ TM 5-1300 FIG 5-5

$I_c = .0425(1)(16)^3$ $P = .00992$

$I_c = 174.08$ $n = \frac{29 \times 10^6}{4.29 \times 10^6} = 6.76$

$I_g = \frac{bT_c^3}{12}$ $F = .0425$

$I_g = \frac{1(18)^3}{12} = 486$

MODIFY FOR ROUND SLAB FROM HARRIS & CREDE P1-15 USE CONSTANTS 5.90 ROUND 5.70 SQ

$T = \frac{1}{f_n} = .00993$ SEC.

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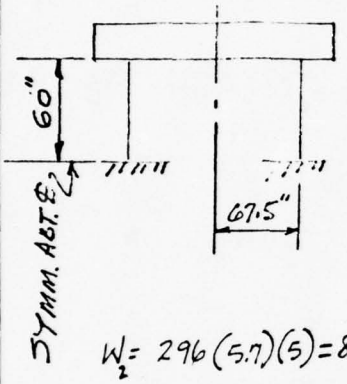
DETERMINE NATURAL FREQUENCY WF ONLY WITHOUT WT. OF ROOF SLAB



$A = 296 \times 1.67 = 494.32 \square''$

$K_2 = \frac{AE}{L} = \frac{494.32\,(29)(10^6)}{60} = 2.389 \times 10^8$

$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{\frac{W}{g}}}$

$W_2 = 296(5.7)(5) = 8436^{\#}$

$f_n = \frac{1}{2\pi}\sqrt{\frac{2.389 \times 10^8}{\frac{8436}{386}}}$

$m_2 = \frac{8436}{386} = 21.85^{\#\,SEC^2/IN}$

$f_n = 526$ CPS

$T = \frac{1}{f_n} = \frac{1}{526} = .0019$ SEC

NOTE: SINCE $2T_{WF} < T_{SLAB}$ ∴ USE T OF SLAB FOR DES.
(FREQUENCIES CANNOT BE COMBINED WHEN ONE SYSTEM IS GREATER THAN 2 TIMES THE OTHER SYSTEM) SEE BIGGS PAGE 233

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SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.H.	DATE:

DETERMINE NATURAL FREQUENCY OF COLUMNS WITH WT. OF ROOF SLAB

$A = 494.32^{a''}$ $\quad K = 2.389 \times 10^8$

W_1 = WT. OF CONC. $= A t (160^{\#}/FT^3) = \frac{\pi (13.33)^2}{4}(1.5)(160) = 33,494^{\#}$

$W_2 = 8436^{\#}$

$$\omega = \sqrt{\frac{Kg}{W_1 + \frac{1}{3}W_2}} = \sqrt{\frac{(2.389)(10^8)(386)}{33,494 + \frac{8436}{3}}} = 1593$$

$$f_n = \frac{\omega}{2\pi} = \frac{1593}{2(\pi)} = 253.6 \text{ CPS}$$

$$T = \frac{1}{f_n} = \frac{1}{253.6} = .00394$$

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SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R.M.N.	DATE: DATE:

CHECK CAPACITY OF SLAB

REDUCE STEEL FOR BENDING AND USE FOR AXIAL LOAD

$\%$ FOR BENDING $= .01115 - \frac{.00615}{2} = .01034$

$K_u = \rho f_y d \left(1 - \frac{PM}{2}\right) = .01034(66{,}000)\left[1 - \frac{.01034(12.42)}{2}\right]$

$K_u = 638.6$

$M_{HP} = K_u b d^2 = 638.6\,(12)(16)^2 = 1{,}961{,}839.3$ "#/FT OR $163{,}486.6$ "#/IN

$M_{VN} = \frac{5{,}580(12)}{1.433} = 49{,}239$ "#/IN

$r_y R^2 = G\,(M_{HP} + M_{VN})$

$r_y = \frac{G(163{,}486.6 + 49{,}239)}{(67.5)^2} = 380$ psi PROVIDED

FROM GRAPH SH. 1A $\quad r_y = 280$

$T = 9.9$ ms

$\mu = 3.2$

DEFLECTION OF SLAB

$X_e\,WF = \frac{PL}{AE} = \frac{3{,}578{,}400\,(60)}{(494.32)(29)(10^6)} = .015$ (SH. 4 / SH. 5)

$X_{e\,SLAB} = .17$ SH. 14

$X_e = .015 + .17 = .185$"

$X_m = \mu X_e = 3.2(.185) = .59$"

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SUBJECT:	COMPUTED BY: E. WILLIAMS CHECKED BY: R. M. H.	DATE: DATE:

DETERMINE r_y REQ'D BASED ON ACTUAL T

$$\left(\frac{\frac{C_1 P_m}{r_y}}{F_1}\right)^2 + \frac{\frac{C_2 P_m}{r_y}}{F_2} = 1$$

$$\left(\frac{3828}{24.48 r_y}\right)^2 + \frac{163}{.845 r_y} = 1$$

$$\left(\frac{156.37}{r_y}\right)^2 + \frac{192.90}{r_y} = 1$$

$$\frac{24451.58}{r_y^2} + \frac{192.90}{r_y} = 1$$

$$\frac{24,451.58 + 192.90 r_y}{r_y^2} = 1$$

$$F_1 = \frac{T}{\pi t_{d_1}} \sqrt{2u-1}$$

$$F_1 = \frac{9.93}{\pi(.3)} \sqrt{2(3.2)-1}$$

$$F_1 = 24.48$$

$$F_2 = \frac{T}{\pi t_{d_2}} \sqrt{2u-1} + \frac{1-\frac{1}{2u}}{1+.7\left(\frac{T}{t_{d_2}}\right)}$$

$$F_2 = \frac{9.93}{\pi(1404)} \sqrt{2(32)-1} + \frac{1-\frac{1}{2(3.2)}}{1+.7\left(\frac{9.93}{1404}\right)}$$

$$F_2 = .845$$

$$r_y^2 - 192.90\, r_y + \left(\frac{192.90}{2}\right)^2 = 24,451.58 + \left(\frac{192.90}{2}\right)^2$$

$$(r_y - 96.45)^2 = 24,451.58 + 9302.60$$

$$r_y - 96.45 = \sqrt{33,754.18}$$

$$r_y = 183.72 + 96.45$$

$$r_y = 280. = 280 \text{ OK}$$

BEST AVAILABLE COPY

SUBJECT:	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.A.	DATE:

CHECK REBOUND

$\frac{t_d}{T} = \frac{29}{9.9} = 2.93 \qquad \mu = 5.7$

FROM ASCE No. 42, FIG. 9.1.4

$\frac{r_r}{r_y} = -.45 \qquad r_r = -0.45 r_y = -0.45(280) = 126$

$r_r = \frac{G(M_{HP} + M_{VN})}{R^2} = \frac{6\left[\frac{163,486.6}{2} + 49,239.\right]}{(67.5)^2} = 172 > 126$ OK

DETERMINE TIME FOR MAXIMUM RESPONSE, $t_m + t_a$

$\frac{t_m}{T} = .96 \qquad t_m = .96\,(.0099) = .0095$ SEC OR 9.5 MS (SH. 16)

$t_a = t_x \left(\frac{Y}{Y_0}\right)^{1/3} = .28\left(\frac{48}{7000}\right)^{1/3} = .081$ MS

KINNEY EXPLOSIVE SHOCKS IN AIR PAGE 180

$t_m + t_a = 9.5 + .081 = 9.581$ MS

$t = \frac{d}{v} = \frac{5.625\ FT}{7200\ FT/SEC} = .00078$ SEC OR .78 MS

BEST AVAILABLE COPY

	COMPUTED BY: E. WILLIAMS	DATE:
	CHECKED BY: R.M.N.	DATE:

FRAGMENT ANALYSIS

USING TM 5-1300 CHAPTER 8

$X_f = 0.162\,(10^{-5})\,W_f^{0.4}\,V_S^{1.8}$ $\quad W_f = .25$, $V_S = 7200$ FT/SEC

$X_f = 0.162\,(10^{-5})(.25)^{0.4}(7200)^{1.8}$

$X_f = 8.16"$

$X_f' = k X_f$ ASSUME MILD STEEL $k = .70$

$= .70(8.16) = 5.7"$

$C_S = 5.16\,E_c^{1/2} = 5.16\sqrt{4.29 \times 10^6} = 10688$

$$C_1 = \left[\frac{T_c + 0.348\,W_f^{1/3}}{X_f'} - 1\right]\left[\frac{C_S}{V_S}\right]^{1/3}$$

$$C_1 = \left[\frac{18 + 0.348\,(.25)^{1/3}}{5.7} - 1\right]\left[\frac{10688}{7200}\right]^{1/3} = 2.474$$

$\dfrac{W_f^{1/3}}{X_f'} = \dfrac{(.25)^{1/3}}{5.7} = .11$ FROM FIG. 8-4

NO SPALLING WILL OCCUR

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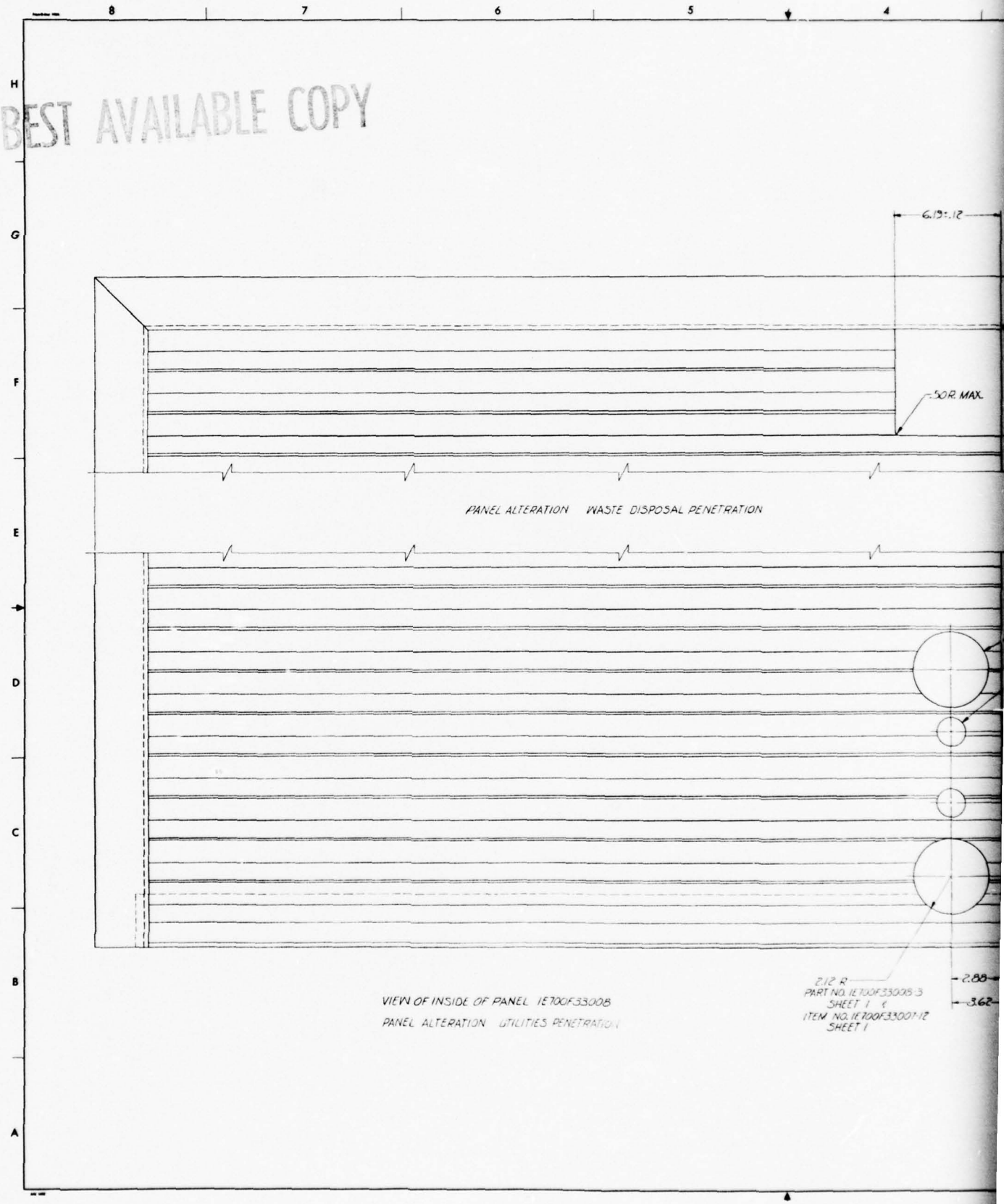
APPENDIX I - DRAWINGS

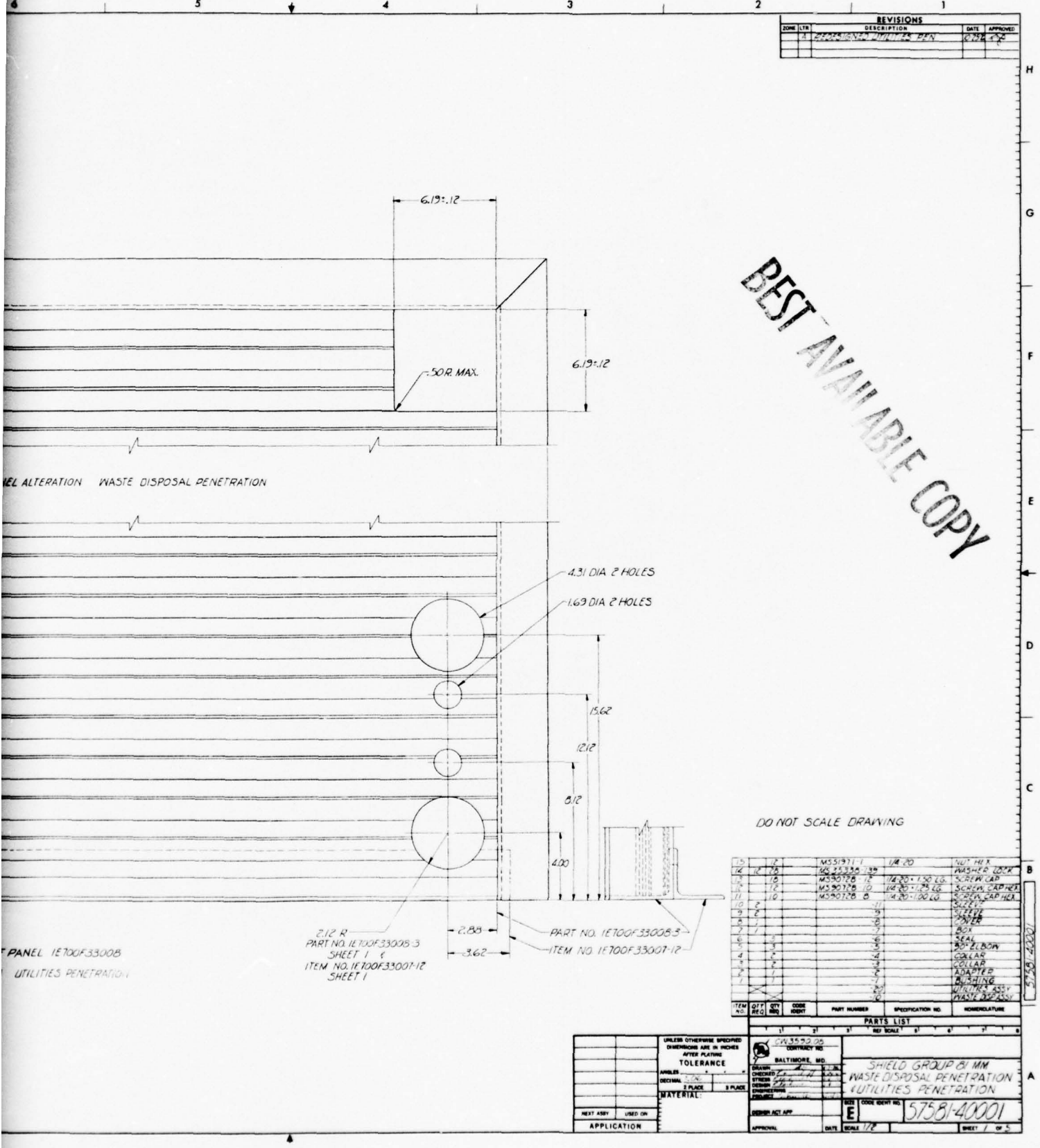
(The following drawings show the details of the various penetrations for each safety approved shield group.)

BEST AVAILABLE COPY



VIEW OF INSIDE OF PANEL IE700F33008

PANEL ALTERATION UTILITIES PENETRATION



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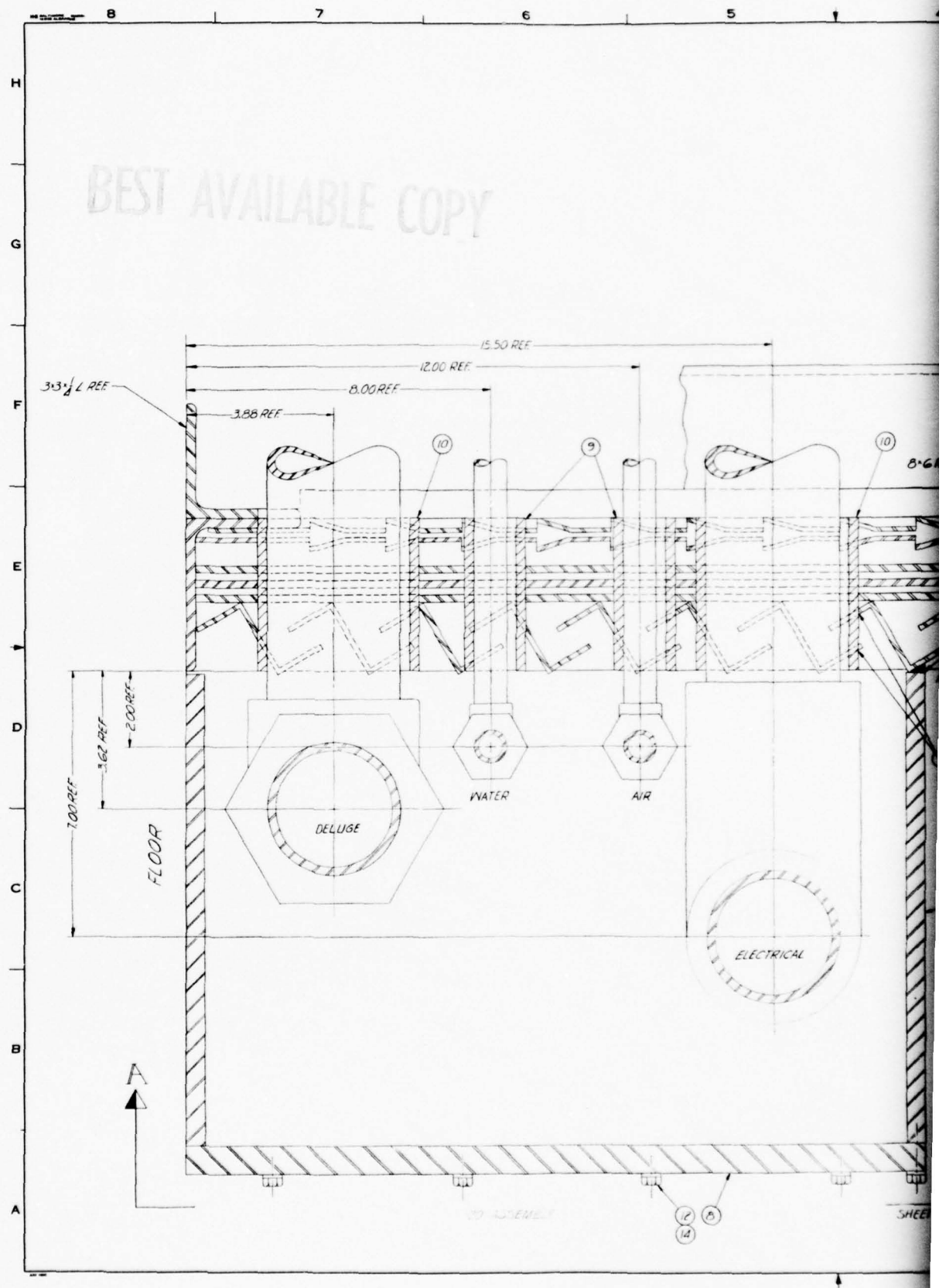

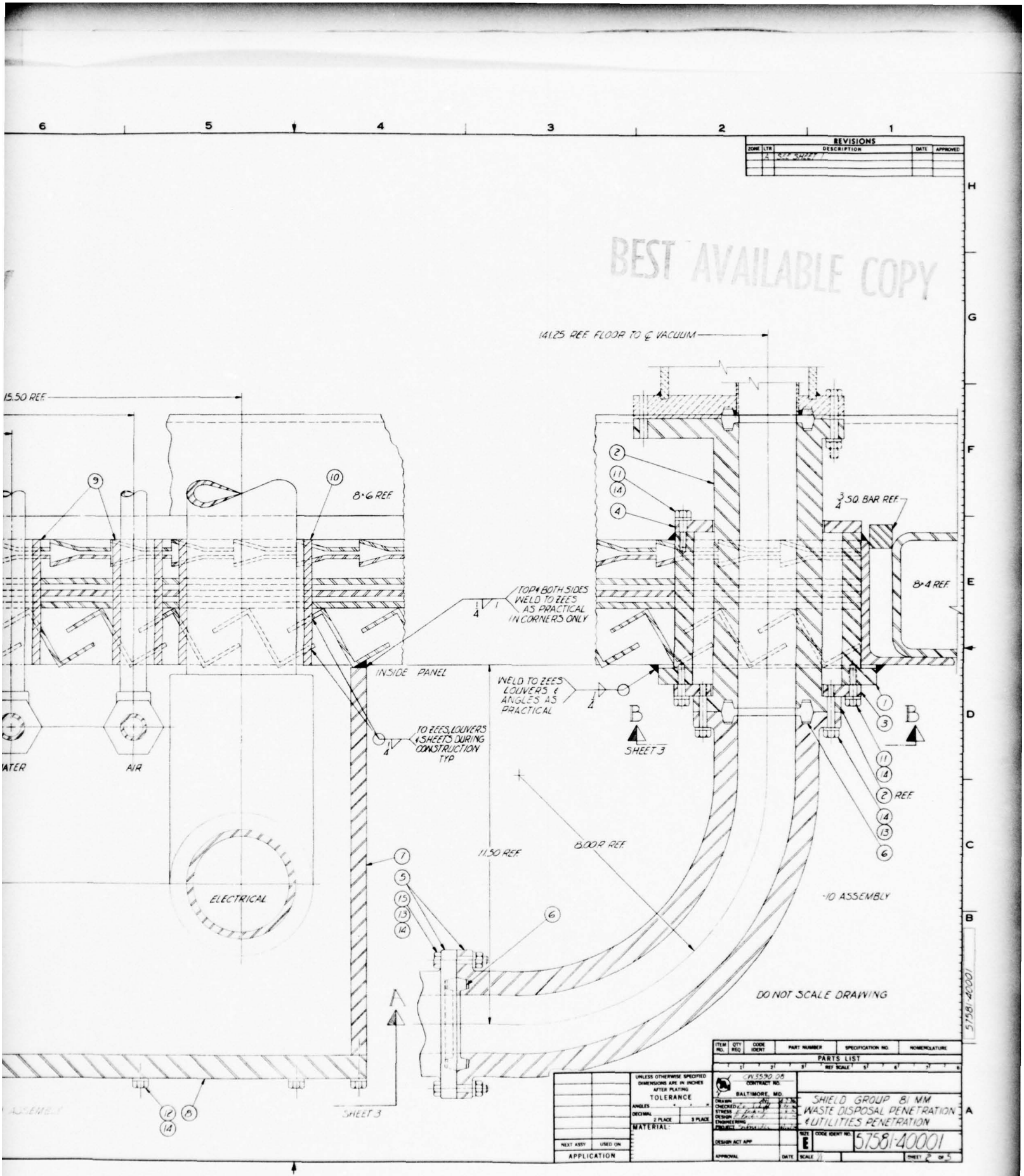

151

152 Blank

2

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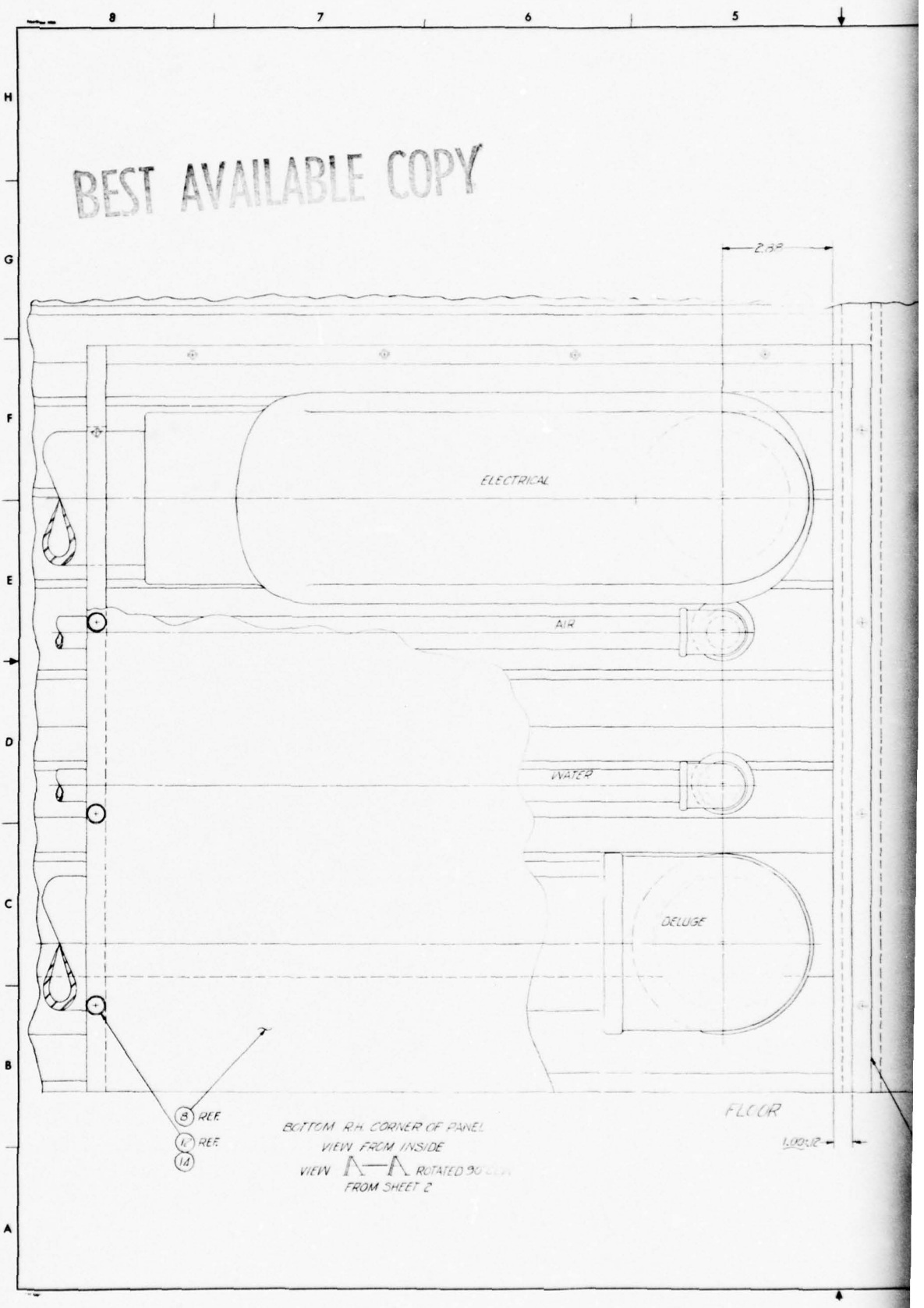
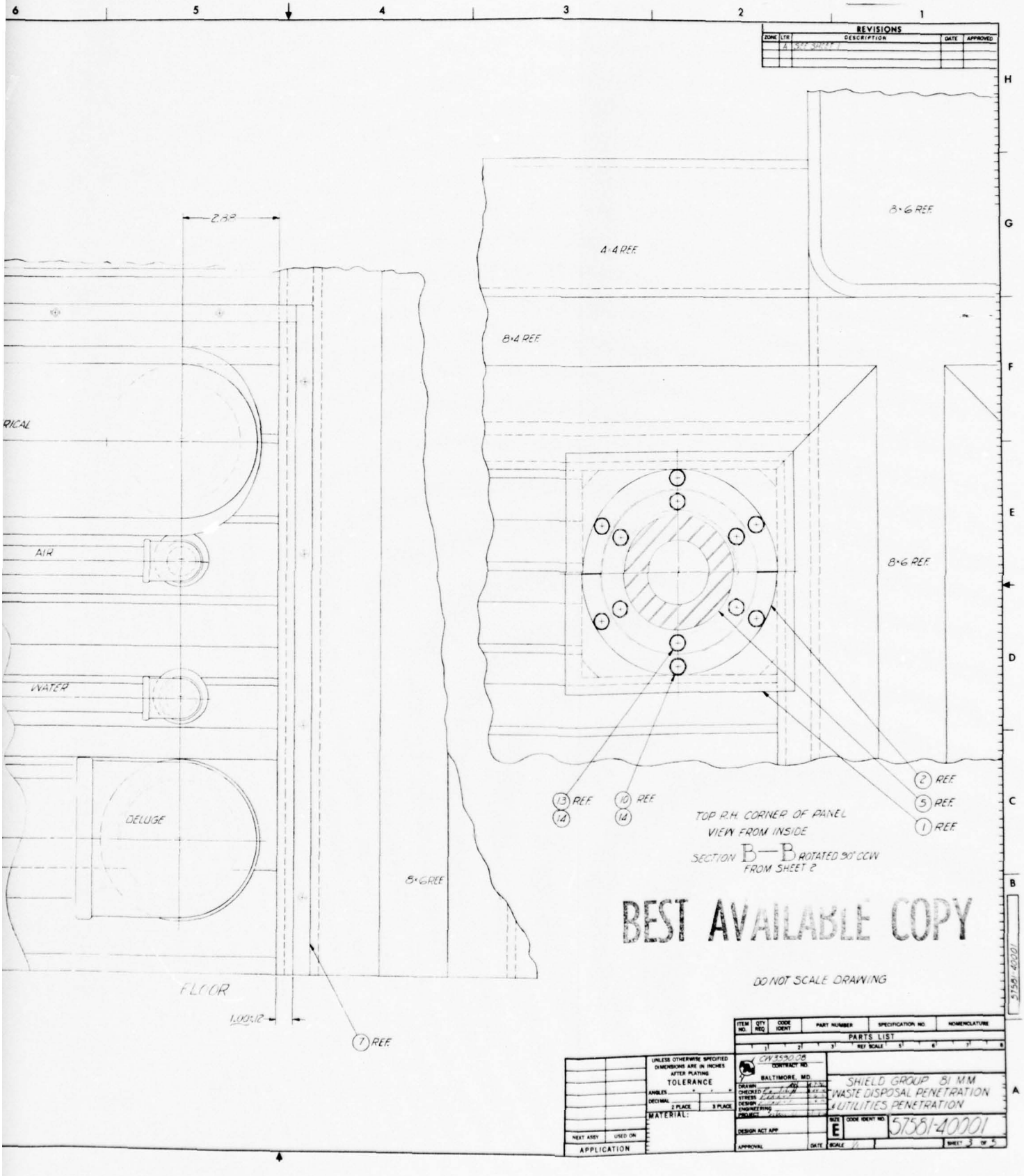
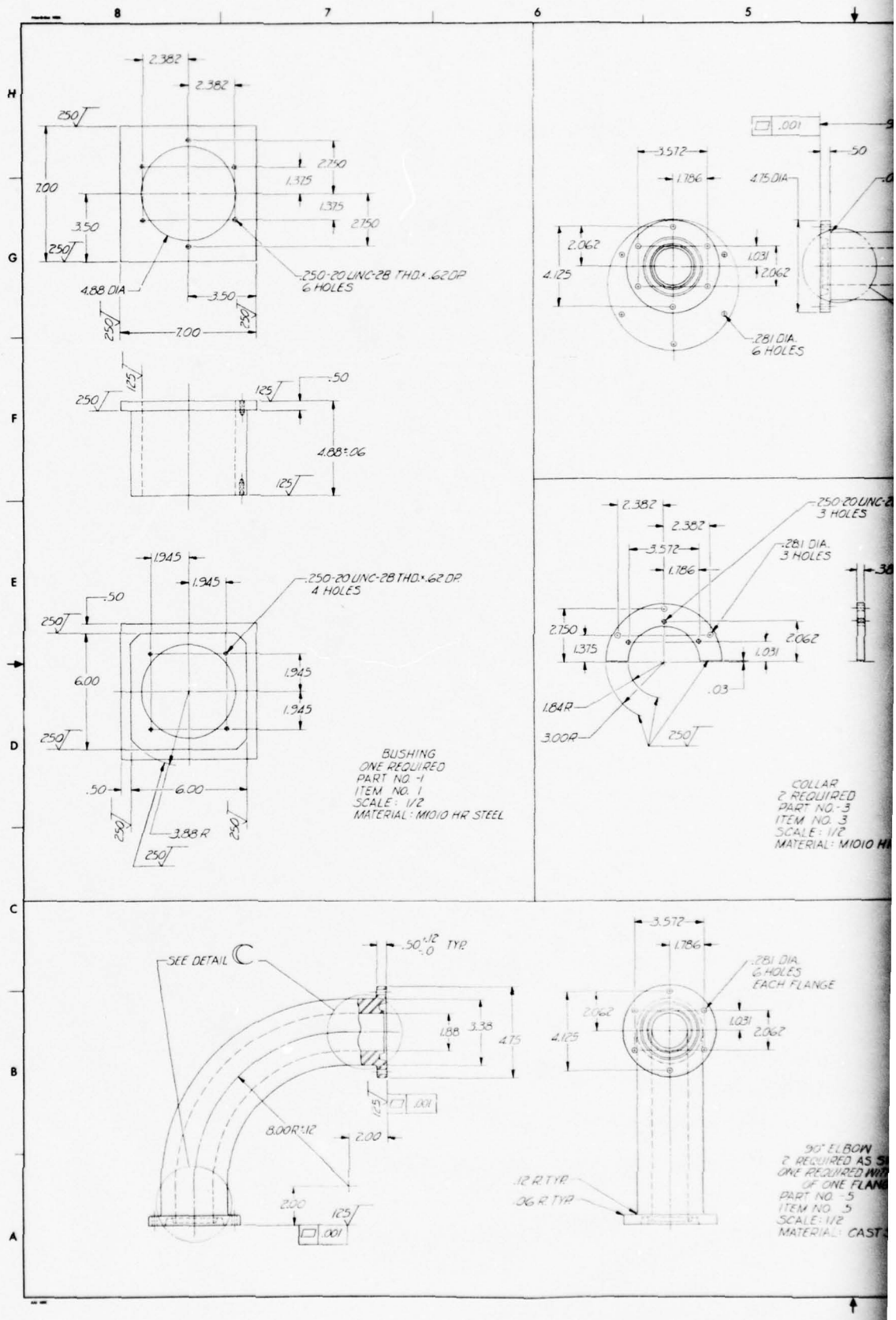
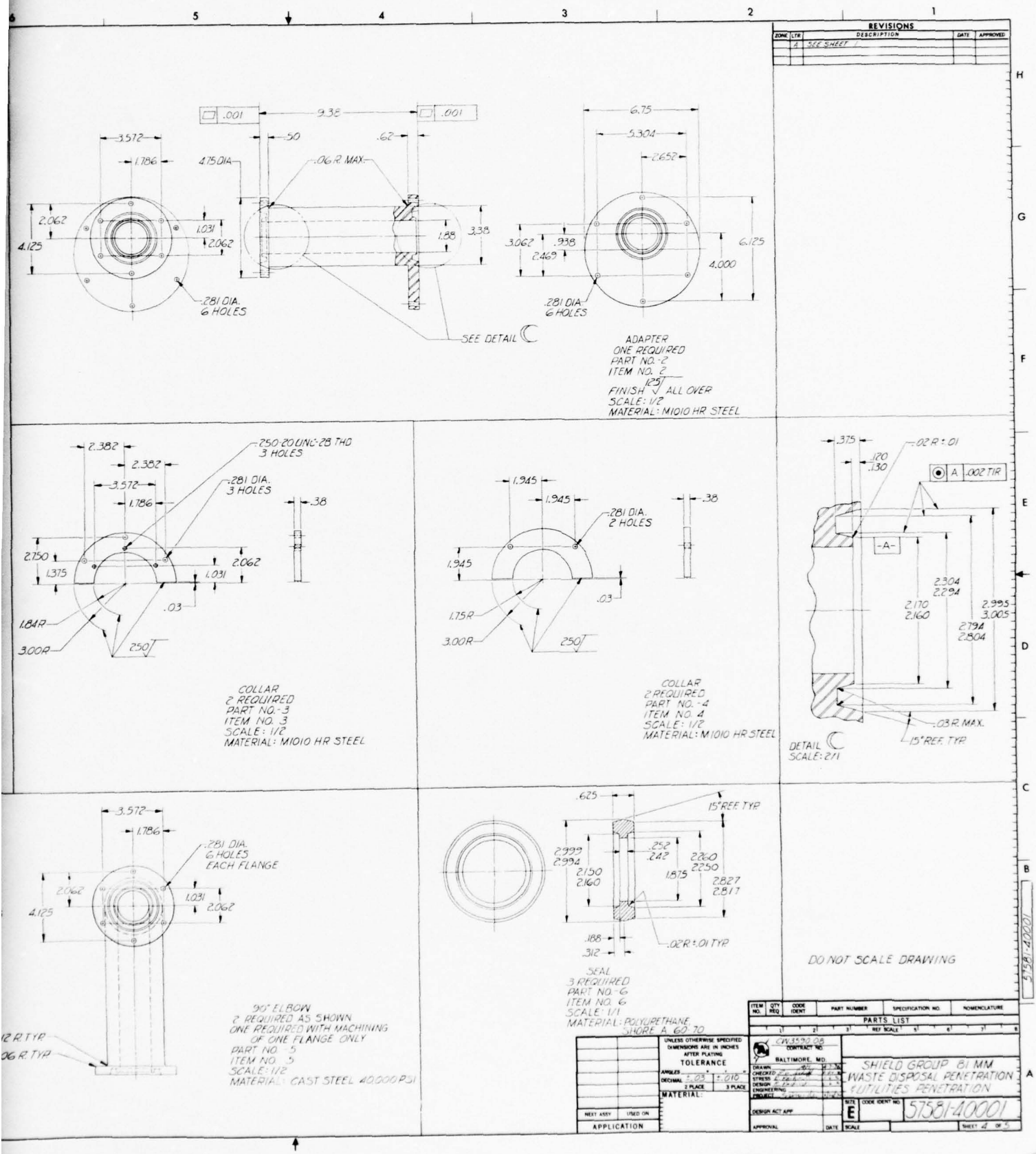



6
5
4
3
2
1
REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A SEE SHEET 1
H
G
F
E
D
C
B
A
2.88
4.4 REF.
8.6 REF.
8.4 REF.
8.6 REF.
AIR
WATER
DELUGE
8.6 REF.
FLOOR
1.00±12
(1) REF.
(2) REF.
(5) REF.
(1) REF.
(13) REF.
(12)
(10) REF.
(14)
TOP R.H. CORNER OF PANEL
VIEW FROM INSIDE
SECTION B—B ROTATED 90° CCW
FROM SHEET 2
BEST AVAILABLE COPY
DO NOT SCALE DRAWING
57581-40001
PARTS LIST
ITEM NO. | QTY REQ | CODE IDENT | PART NUMBER | SPECIFICATION NO. | NOMENCLATURE
CW3590-08
CONTRACT NO.
BALTIMORE, MD.
SHIELD GROUP 81 M.M.
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION
SIZE E
CODE IDENT NO.
57581-40001
SHEET 3 OF 5
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES
DECIMAL
2 PLACE
3 PLACE
MATERIAL:
NEXT ASSY
USED ON
APPLICATION
DESIGN ACT APP
APPROVAL
DATE
SCALE


8
7
6
5
H
G
F
E
D
C
B
A
2.382
2.382
.250
7.00
2.750
1.375
1.375
2.750
3.50
.250
4.88 DIA
3.50
.250
.250
7.00
.250-20 UNC-2B THD x .62 DP
6 HOLES
.001
3.572
.50
1.786
4.75 DIA
2.062
1.031
2.062
4.125
.281 DIA.
6 HOLES
.125
.250
.125
.50
4.88±.06
.125
1.945
1.945
.250-20 UNC-2B THD x .62 DP
4 HOLES
.50
.250
6.00
1.945
1.945
.250
.50
6.00
.250
.250
3.88 R
.250
BUSHING
ONE REQUIRED
PART NO. -1
ITEM NO. 1
SCALE: 1/2
MATERIAL: M1010 HR STEEL
2.382
2.382
3.572
1.786
.250-20 UNC-2
3 HOLES
.281 DIA.
3 HOLES
.38
2.750
1.375
2.062
1.031
.03
1.84 R
3.00 R
.250
COLLAR
2 REQUIRED
PART NO. -3
ITEM NO. 3
SCALE: 1/2
MATERIAL: M1010 H
SEE DETAIL C
.50 +.12 -0 TYP.
1.88
3.38
4.75
.001
8.00 R ±.12
2.00
2.00
.125
.001
3.572
1.786
.281 DIA.
6 HOLES
EACH FLANGE
2.062
1.031
2.062
4.125
.12 R TYP.
.06 R TYP.
90° ELBOW
2 REQUIRED AS S
ONE REQUIRED WIT
OF ONE FLANG
PART NO. -5
ITEM NO. 5
SCALE: 1/2
MATERIAL: CAST



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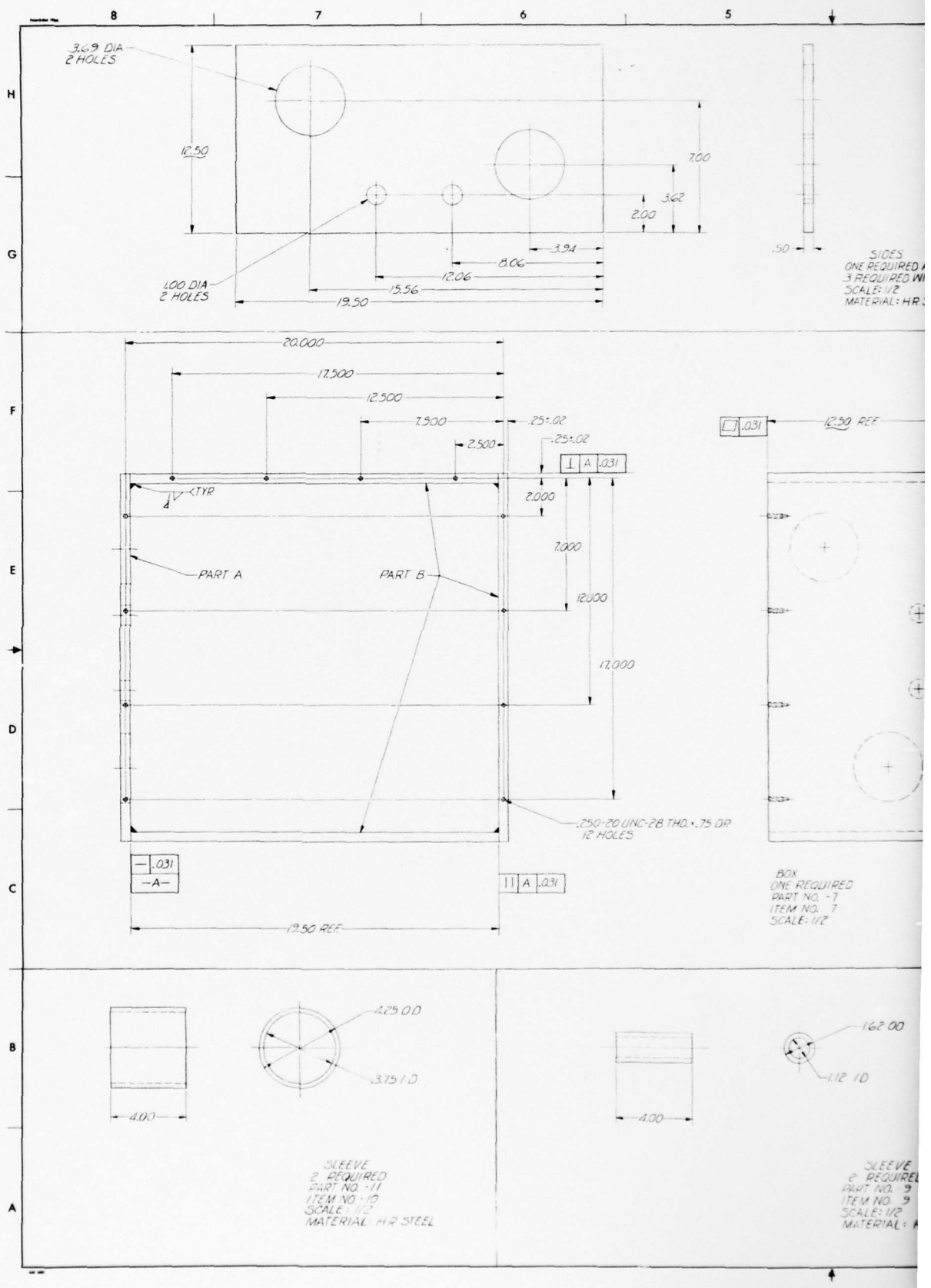
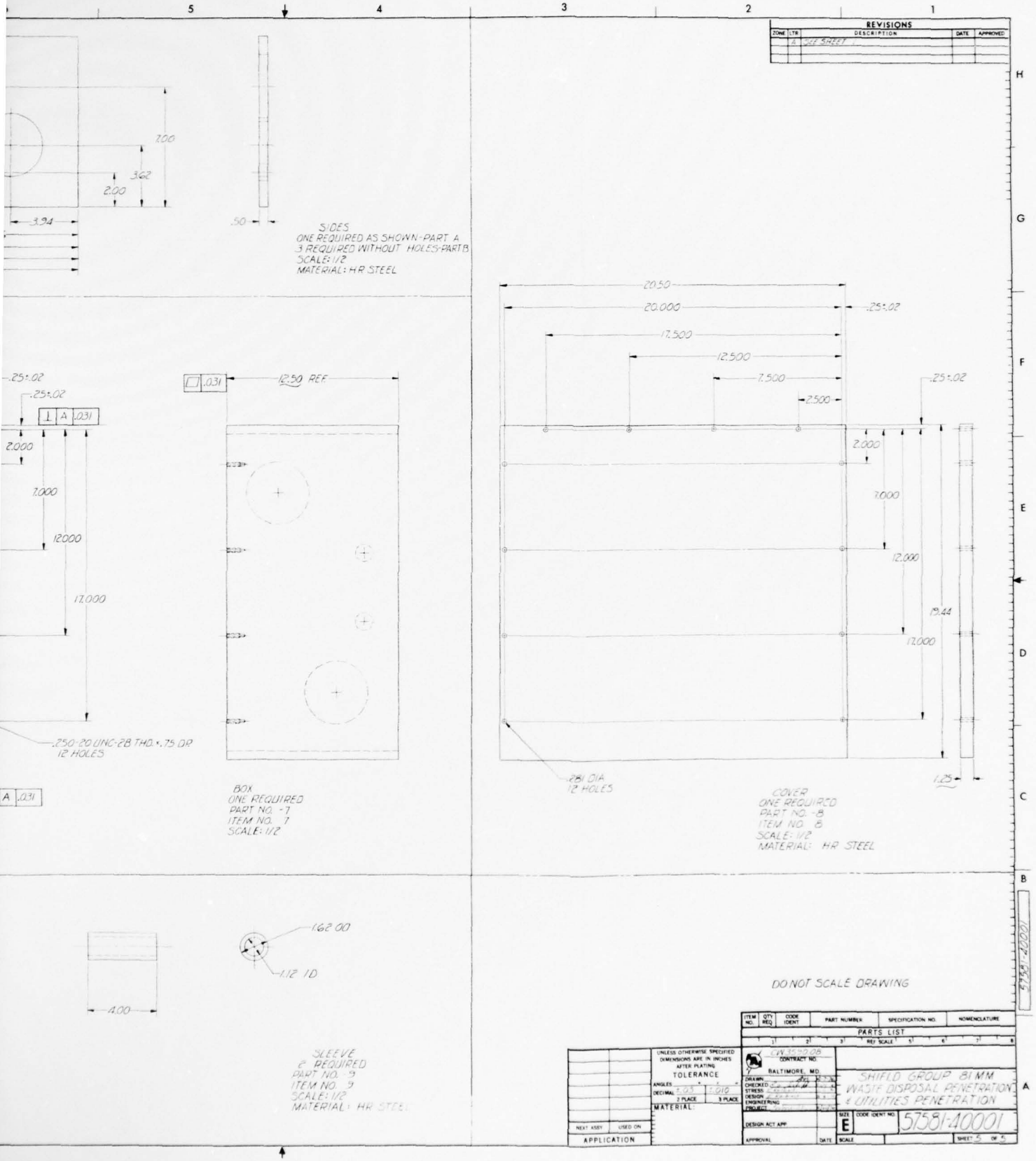

8
7
6
5
H
G
F
E
D
C
B
A
3.69 DIA
2 HOLES
12.50
7.00
3.62
2.00
.50
3.94
8.06
12.06
15.56
19.50
4.00 DIA
2 HOLES
SIDES
ONE REQUIRED
3 REQUIRED
SCALE: 1/2
MATERIAL: HR
20.000
17.500
12.500
7.500
2.500
.25±.02
.25±.02
⊥ A .031
TYP
2.000
7.000
12.000
17.000
PART A
PART B
.250-20 UNC-2B THD. x .75 DP.
12 HOLES
— .031
—A—
11 A .031
19.50 REF
□ .031
12.50 REF
BOX
ONE REQUIRED
PART NO. -7
ITEM NO. 7
SCALE: 1/2
4.25 O.D
3.75 I.D
4.00
SLEEVE
2 REQUIRED
PART NO. -11
ITEM NO. -10
SCALE: 1/2
MATERIAL: HR STEEL
1.62 OD
1.12 ID
4.00
SLEEVE
2 REQUIRED
PART NO. -9
ITEM NO. 9
SCALE: 1/2
MATERIAL:



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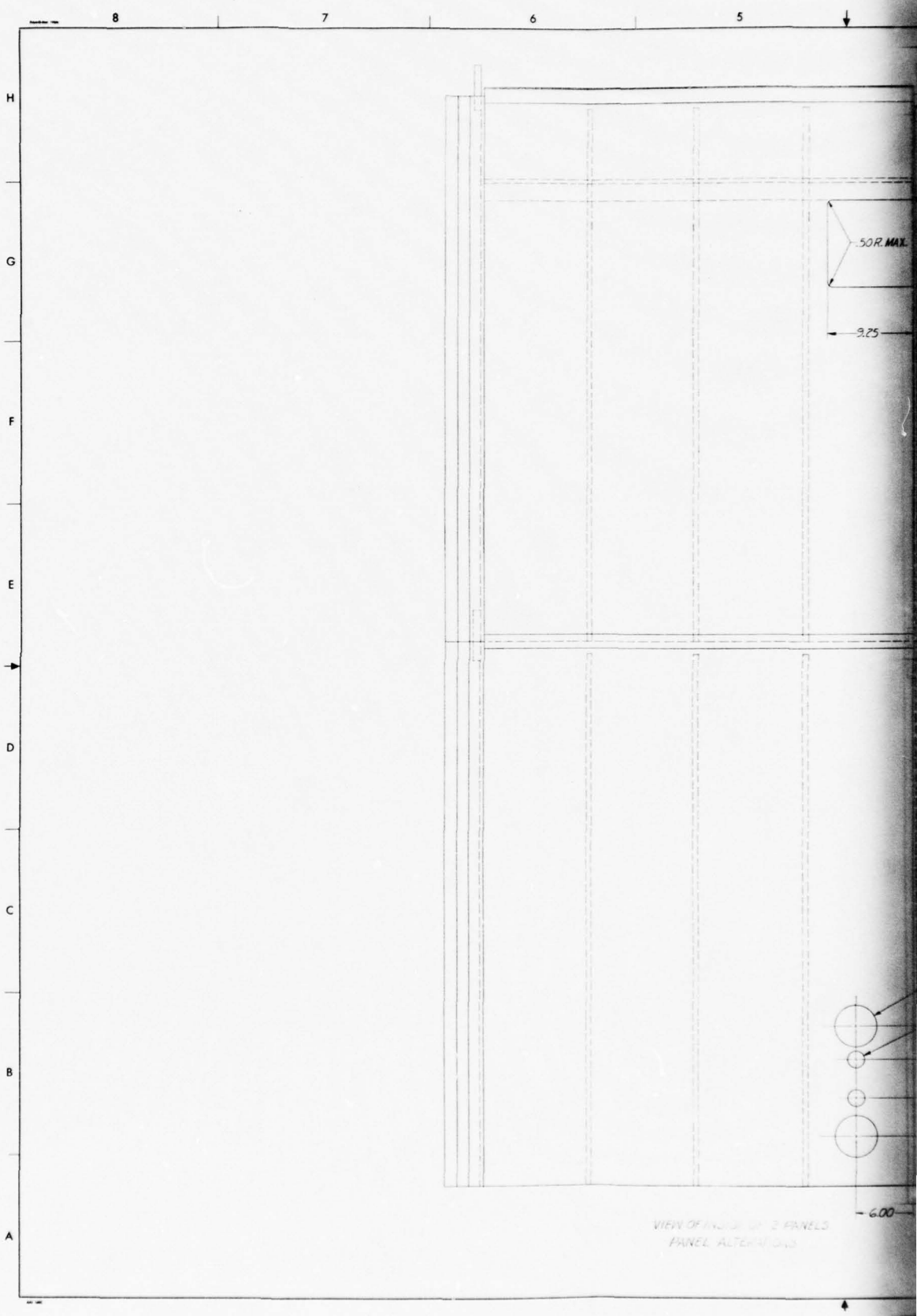
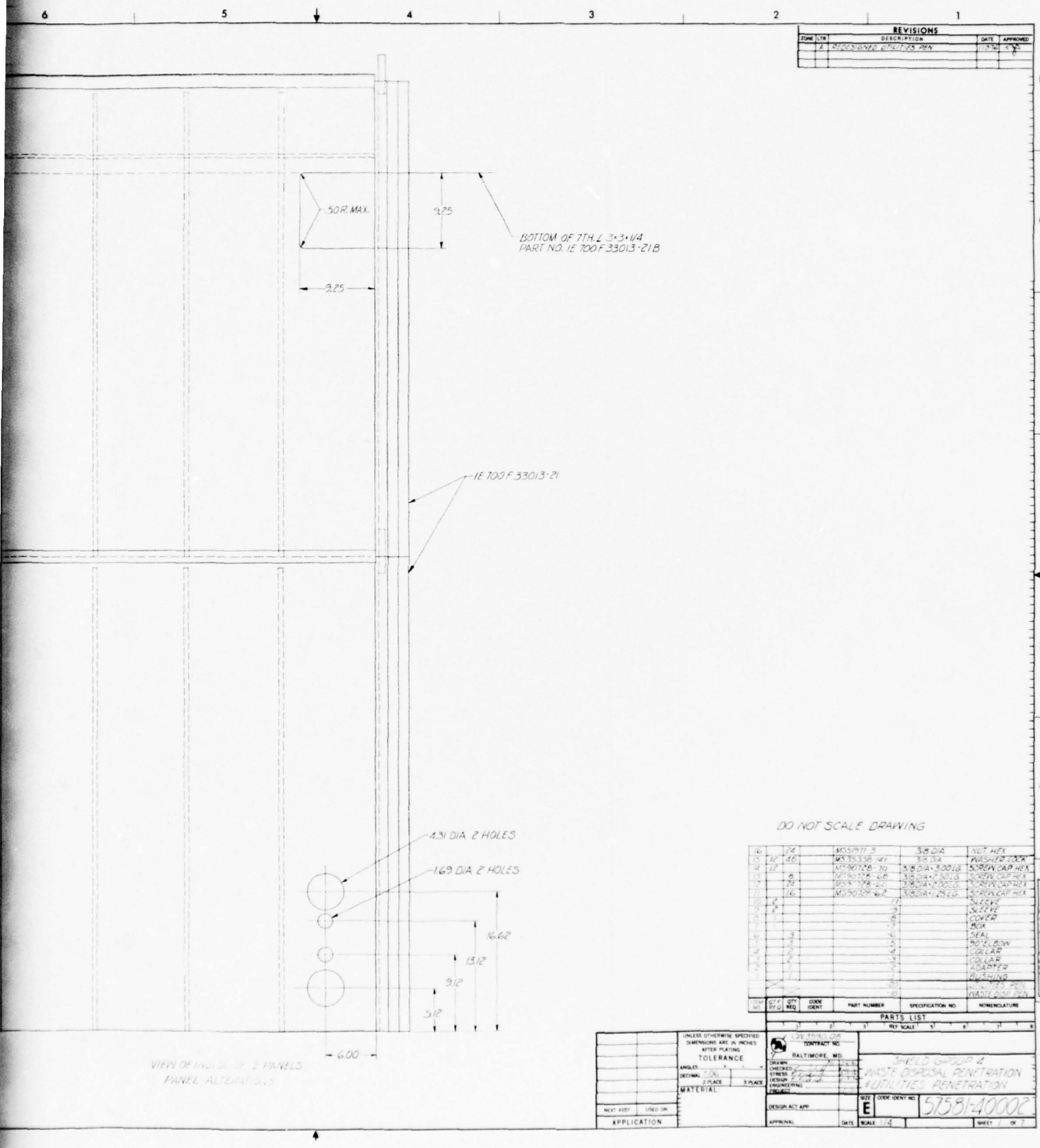

8
7
6
5
H
G
F
E
D
C
B
A
.50 R. MAX.
9.25
6.00



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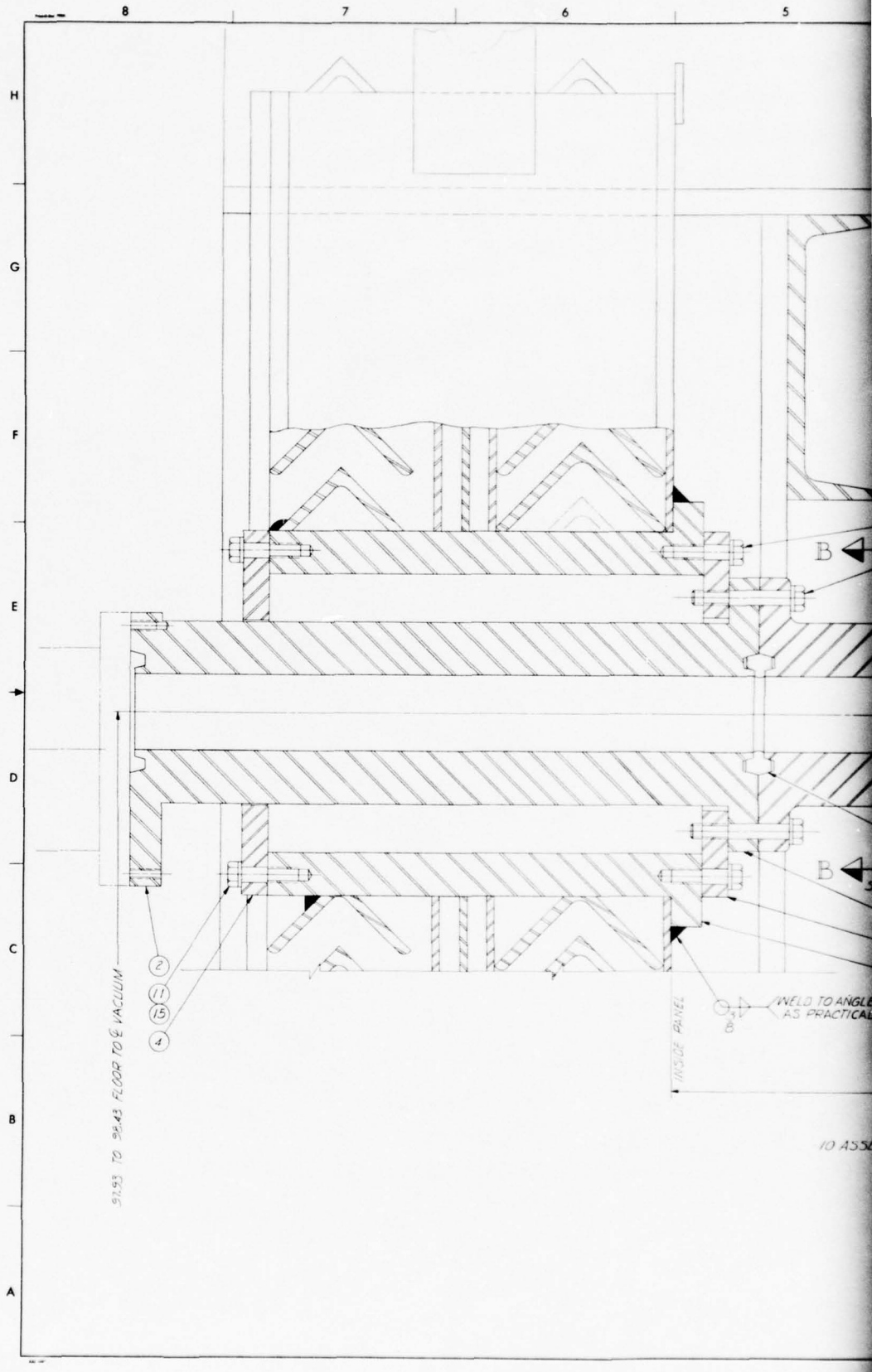
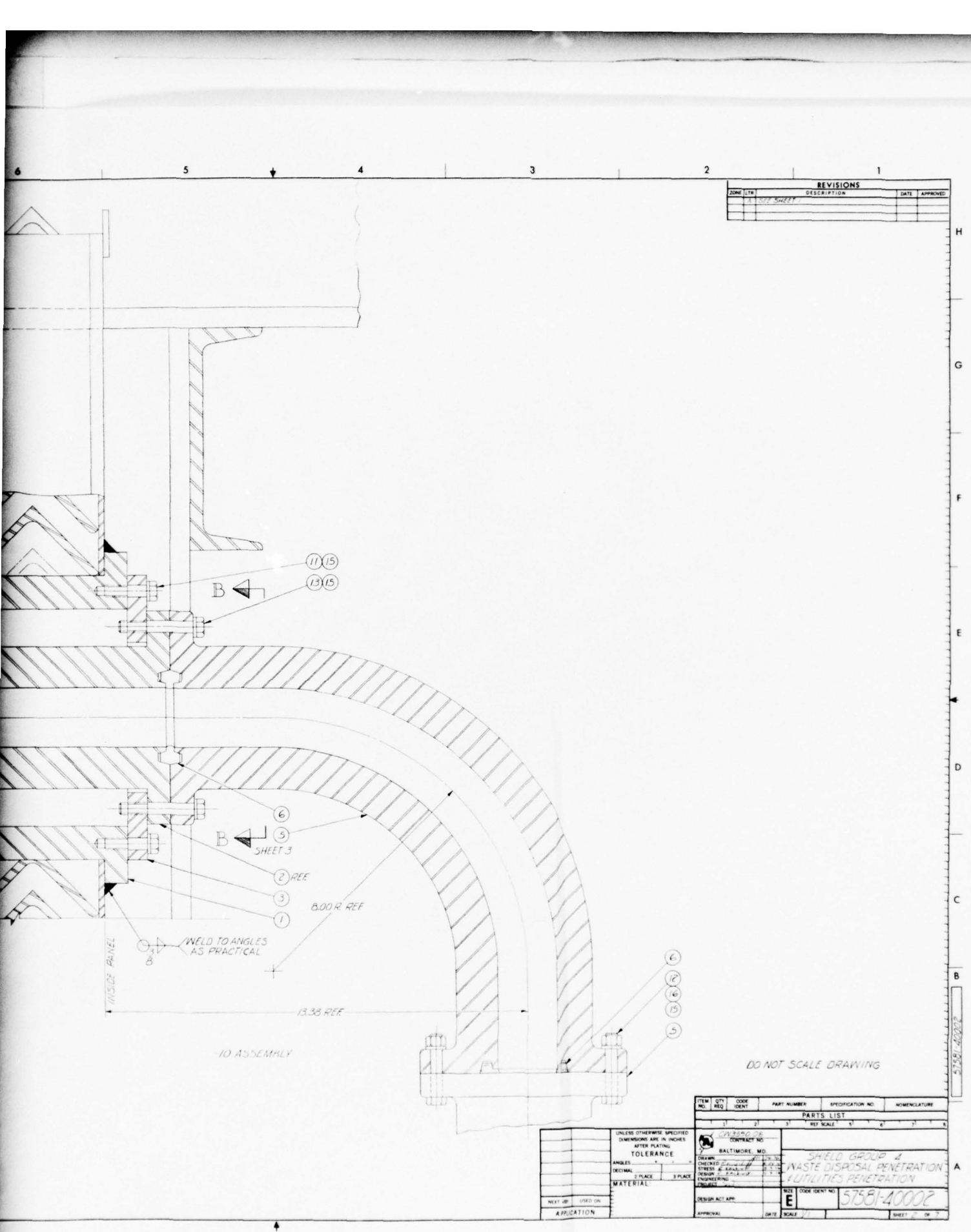

8
7
6
5
H
G
F
E
D
C
B
A
B
B
2
11
15
4
91.93 TO 98.43 FLOOR TO ℄ VACUUM
INSIDE PANEL
WELD TO ANGLE
AS PRACTICAL
B
TO ASS



161

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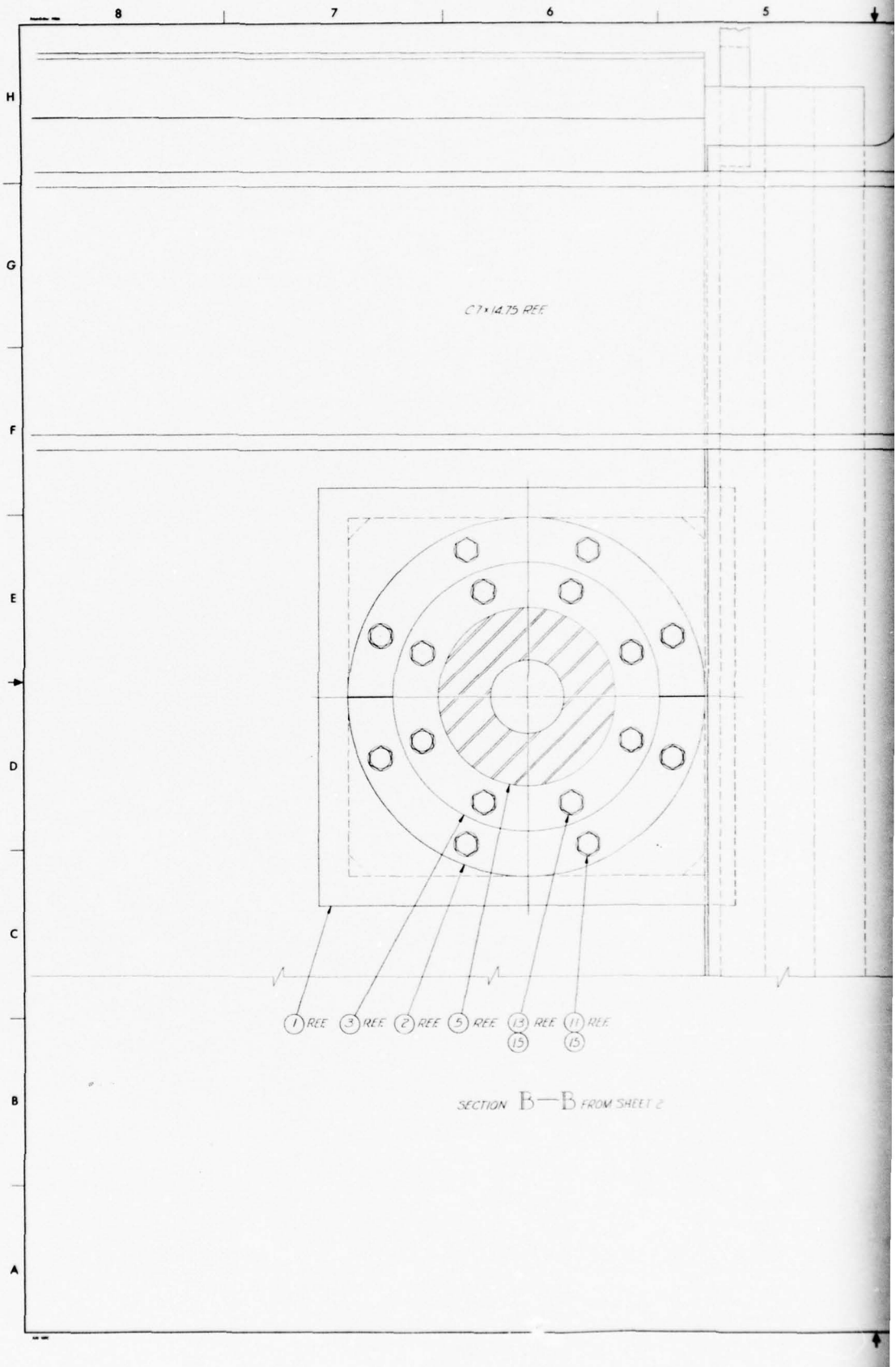
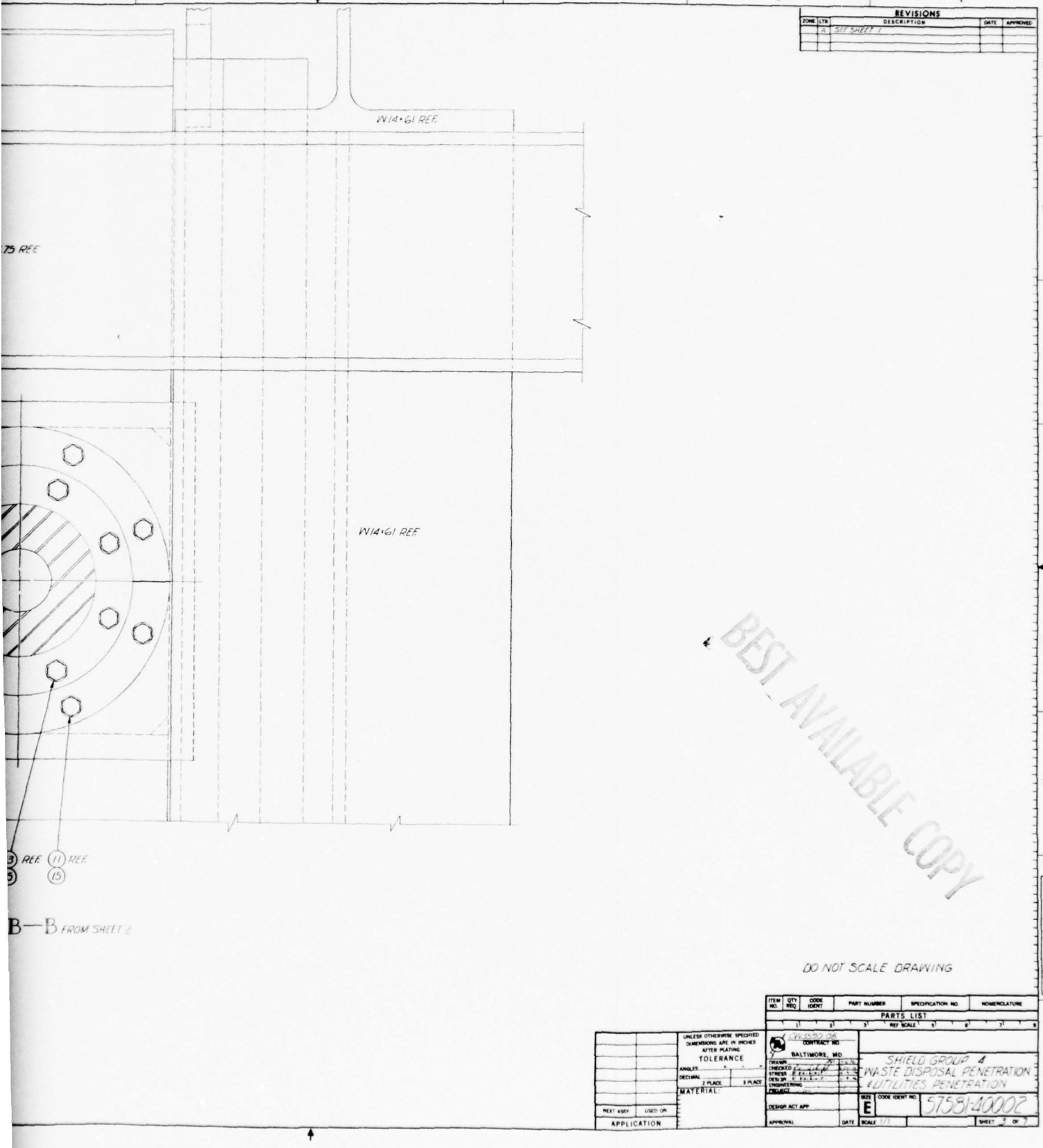

8
7
6
5
H
G
F
E
D
C
B
A
C7×14.75 REF.
(1) REF.
(3) REF.
(2) REF.
(5) REF.
(13) (15) REF.
(11) (15) REF.
SECTION B—B FROM SHEET 2


6
5
4
3
2
1
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
SEE SHEET 1
H
G
F
E
D
C
B
A
W14×61 REF.
75 REF.
W14×61 REF.
3 REF.
11 REF.
15
B—B FROM SHEET 2
BEST AVAILABLE COPY
DO NOT SCALE DRAWING
5758-40002
ITEM NO. QTY REQ. CODE IDENT PART NUMBER SPECIFICATION NO. NOMENCLATURE
PARTS LIST
REF SCALE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES
DECIMAL 2 PLACE 3 PLACE
MATERIAL:
NEXT ASSY USED ON
APPLICATION
CONTRACT NO.
BALTIMORE, MD.
DRAWN
CHECKED
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL DATE
SHIELD GROUP 4
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION
SIZE E
CODE IDENT NO.
5758140002
SCALE
SHEET 3 OF 7

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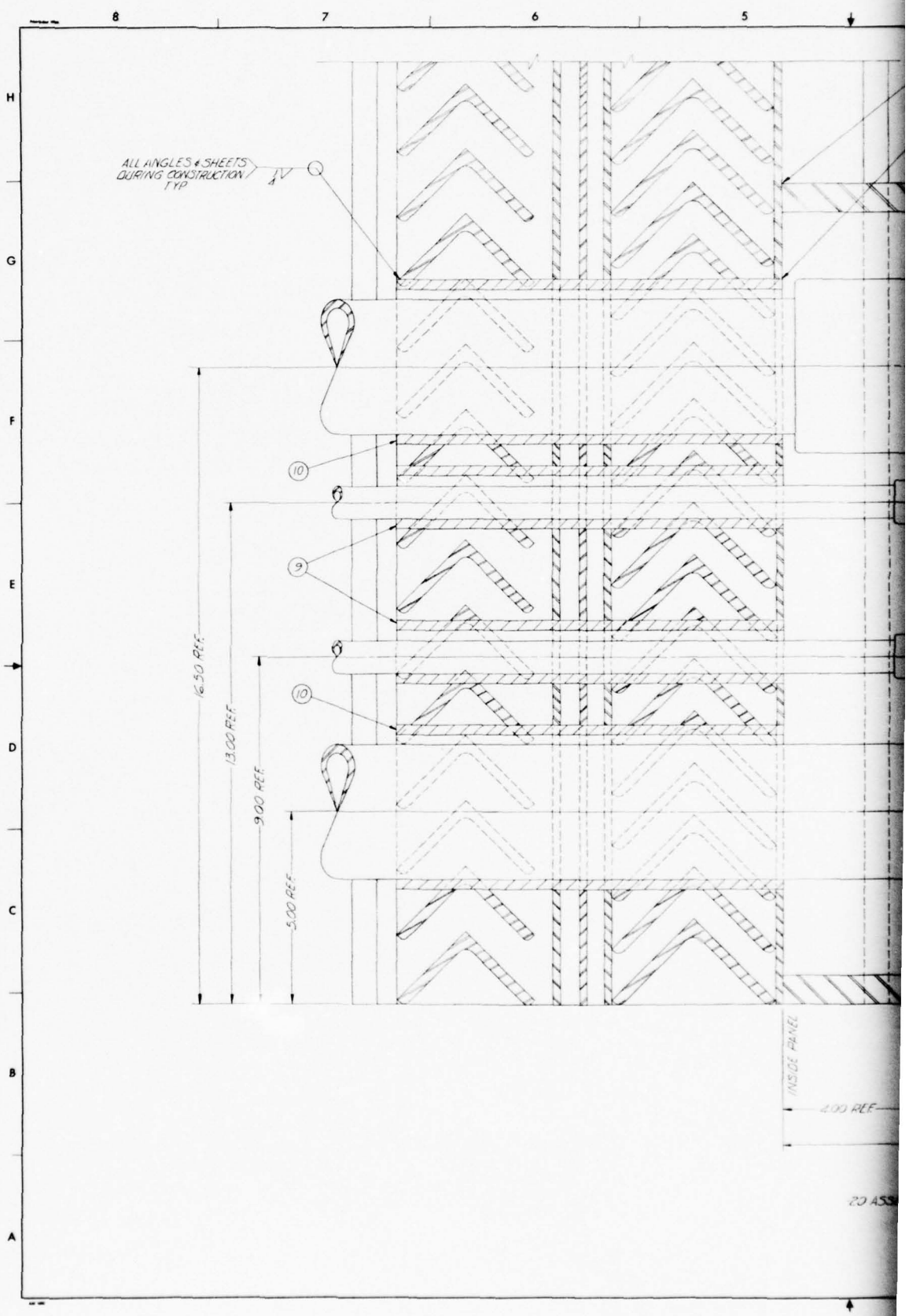
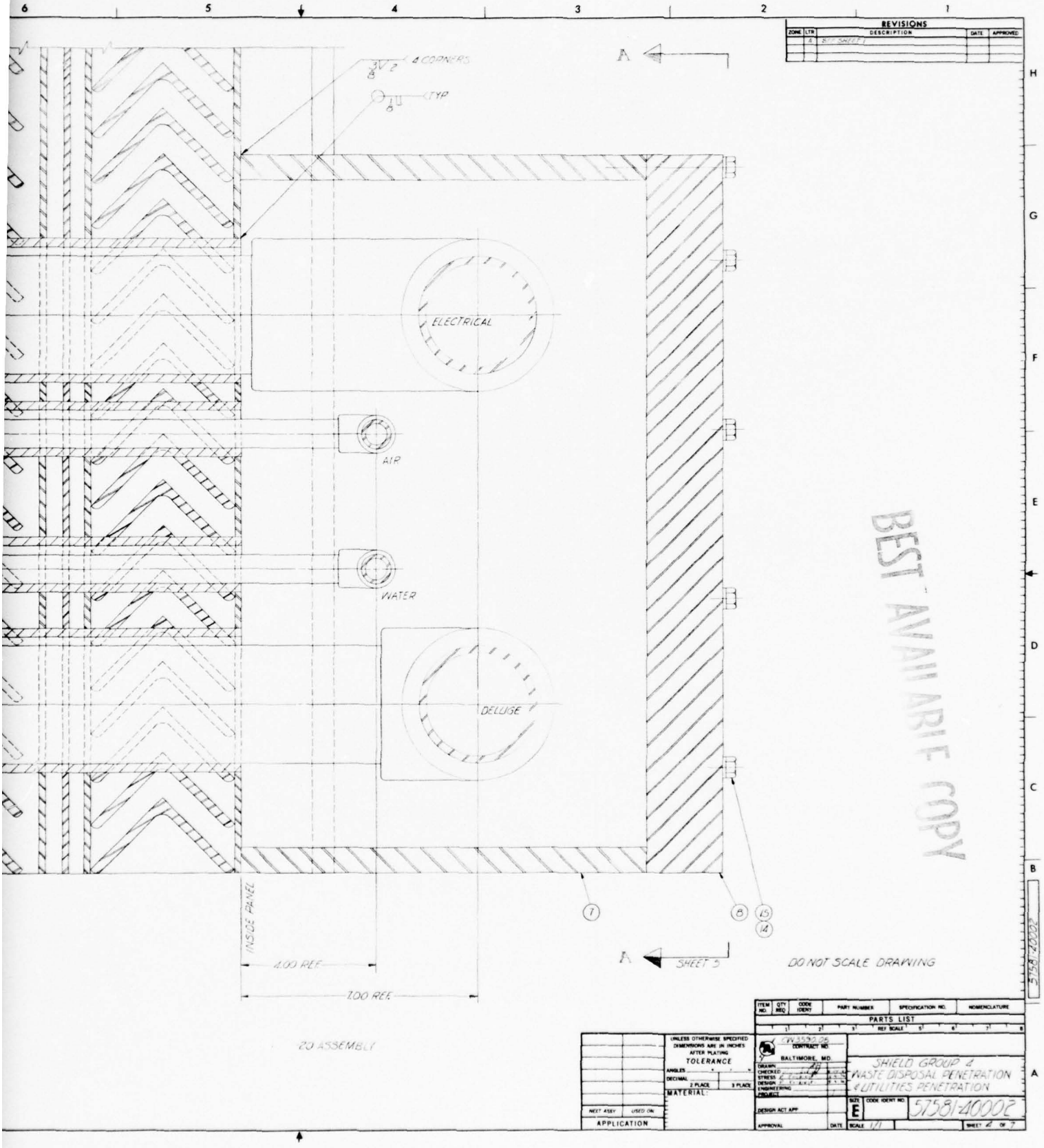
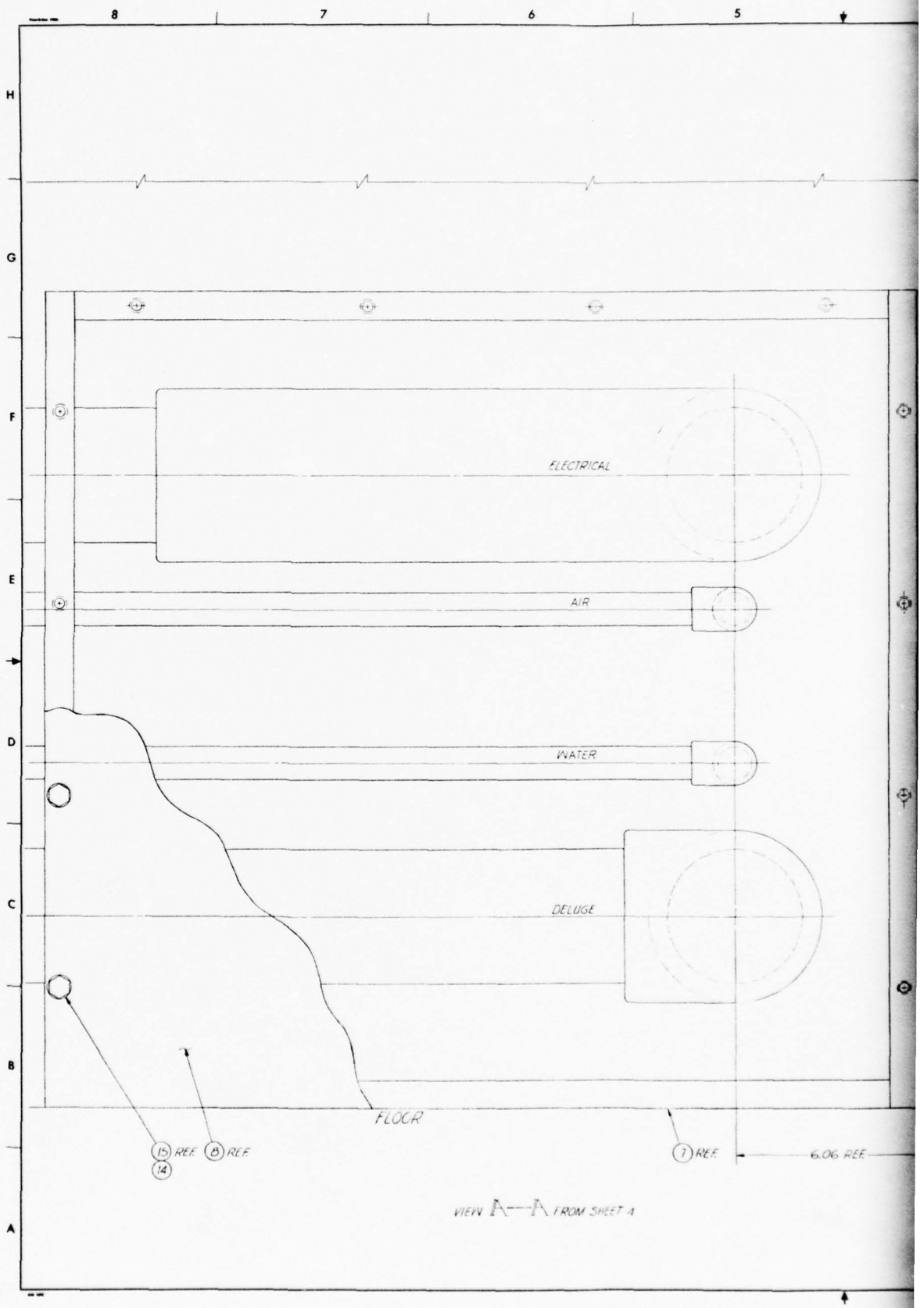

8
7
6
5
H
G
F
E
D
C
B
A
ALL ANGLES & SHEETS DURING CONSTRUCTION / TYP
10
9
10
16.50 REF.
13.00 REF.
9.00 REF.
5.00 REF.
INSIDE PANEL
4.00 REF


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
A SEE SHEET 1
4 CORNERS
TYP
A
ELECTRICAL
AIR
WATER
DELUGE
INSIDE PANEL
40.00 REF.
70.00 REF.
7
8
15
14
A
SHEET 3
DO NOT SCALE DRAWING
BEST AVAILABLE COPY
57581-40002
20 ASSEMBLY
PARTS LIST
ITEM NO. QTY REQ CODE IDENT PART NUMBER SPECIFICATION NO. NOMENCLATURE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
DECIMAL 2 PLACE 3 PLACE
MATERIAL:
NEXT ASSY USED ON
APPLICATION
CONTRACT NO.
BALTIMORE, MD.
DRAWN
CHECKED
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL
DATE
SHIELD GROUP 4
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION
SIZE E
CODE IDENT NO.
57581-40002
SCALE 1/1
SHEET 2 OF 7


8
7
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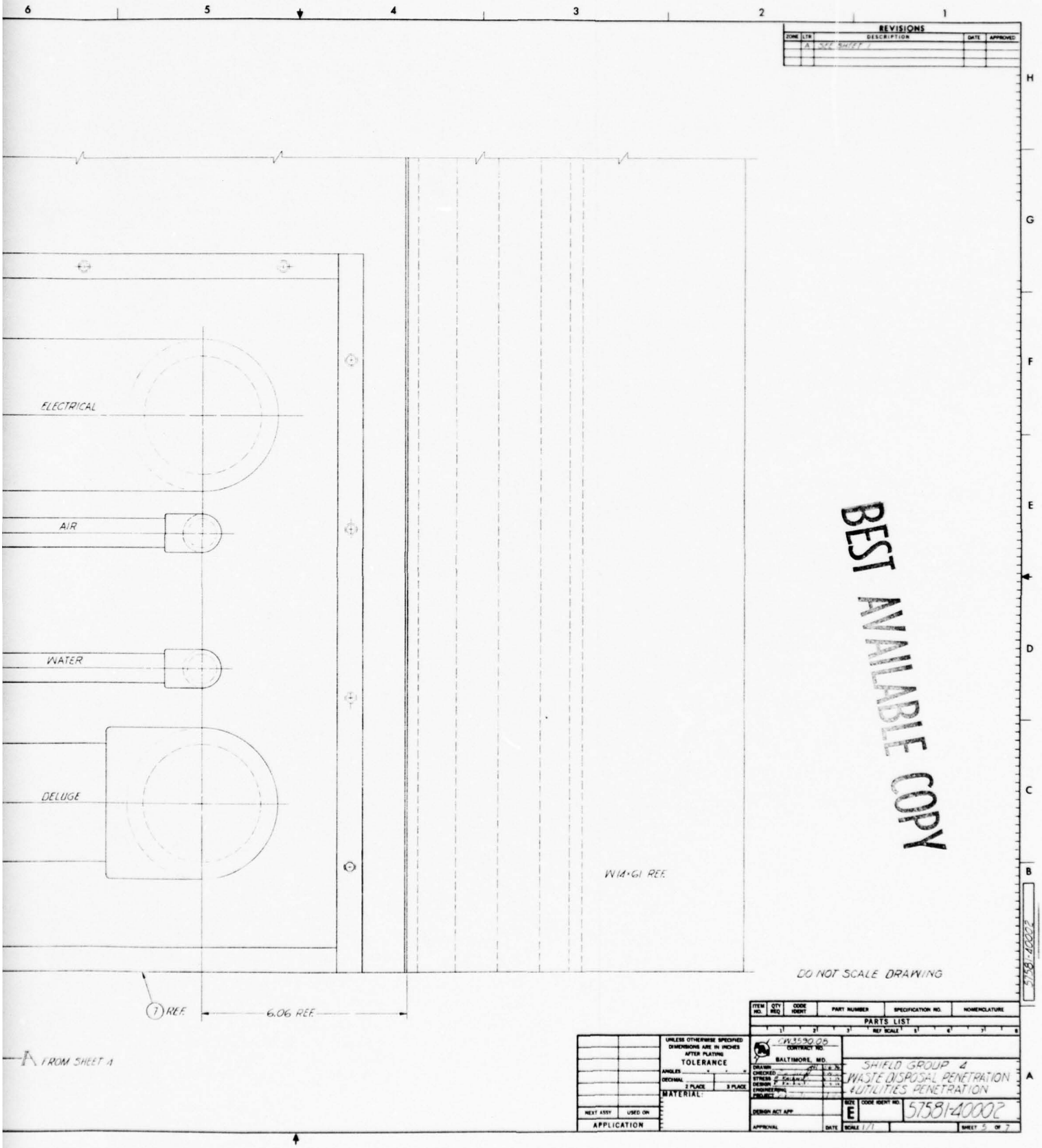
5
H
G
F
E
D
C
B
A
ELECTRICAL
AIR
WATER
DELUGE
FLOOR
(15) REF
(14)
(8) REF
(7) REF
6.06 REF
VIEW A—A FROM SHEET 4


6
5
4
3
2
1
REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A SEE SHEET 1
H
G
F
E
D
C
B
A
ELECTRICAL
AIR
WATER
DELUGE
W14·G1 REF.
7 REF.
6.06 REF.
FROM SHEET 4
DO NOT SCALE DRAWING
BEST AVAILABLE COPY
5758140002
ITEM NO. | QTY REQ | CODE IDENT | PART NUMBER | SPECIFICATION NO. | NOMENCLATURE
PARTS LIST
REF SCALE
CONTRACT NO.
BALTIMORE, MD.
SHIELD GROUP 4
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES
DECIMAL
2 PLACE
3 PLACE
MATERIAL
DRAWN
CHECKED
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL
DATE
NEXT ASSY
USED ON
APPLICATION
SIZE E
CODE IDENT NO.
57581-40002
SCALE 1/1
SHEET 5 OF 7

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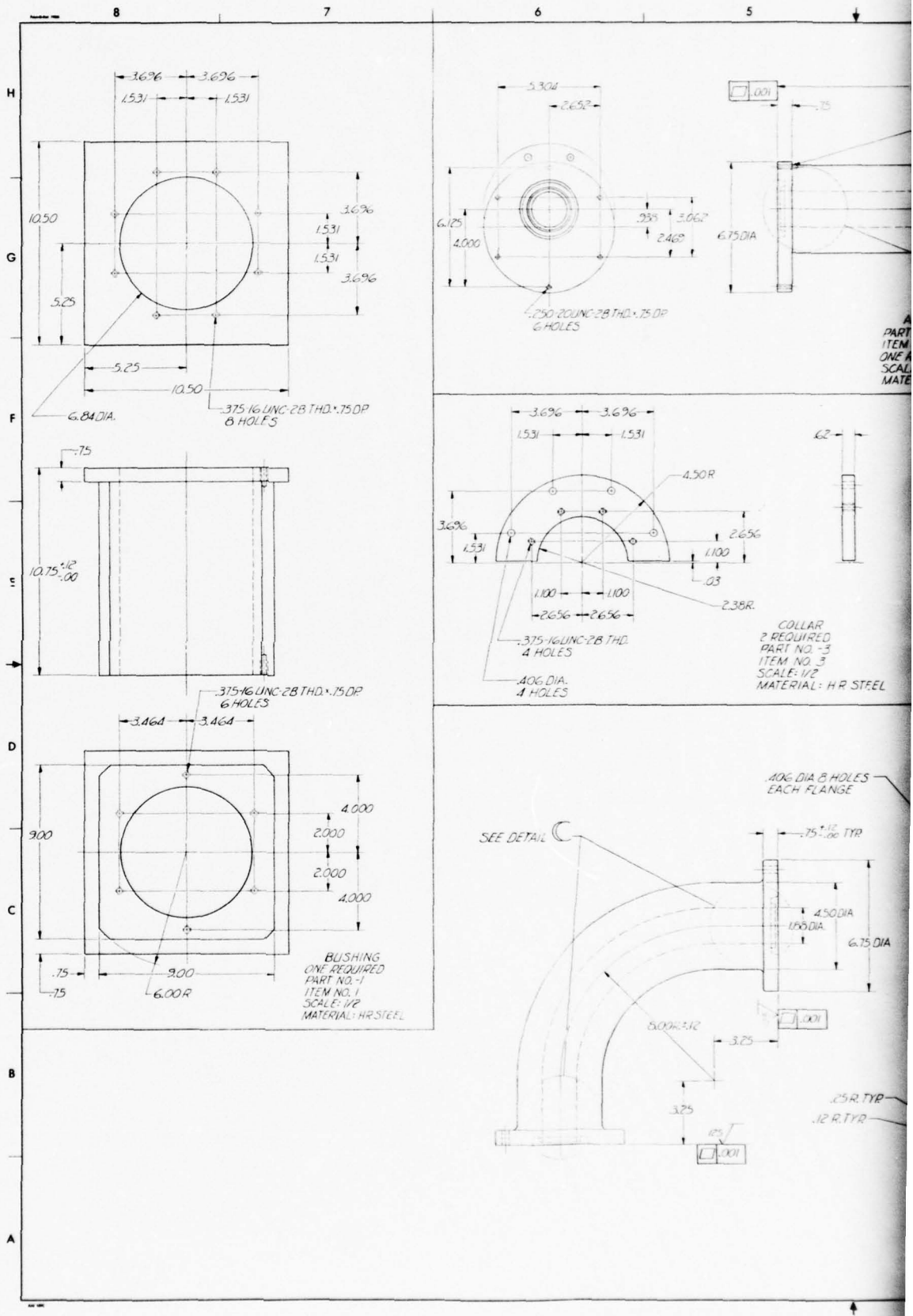
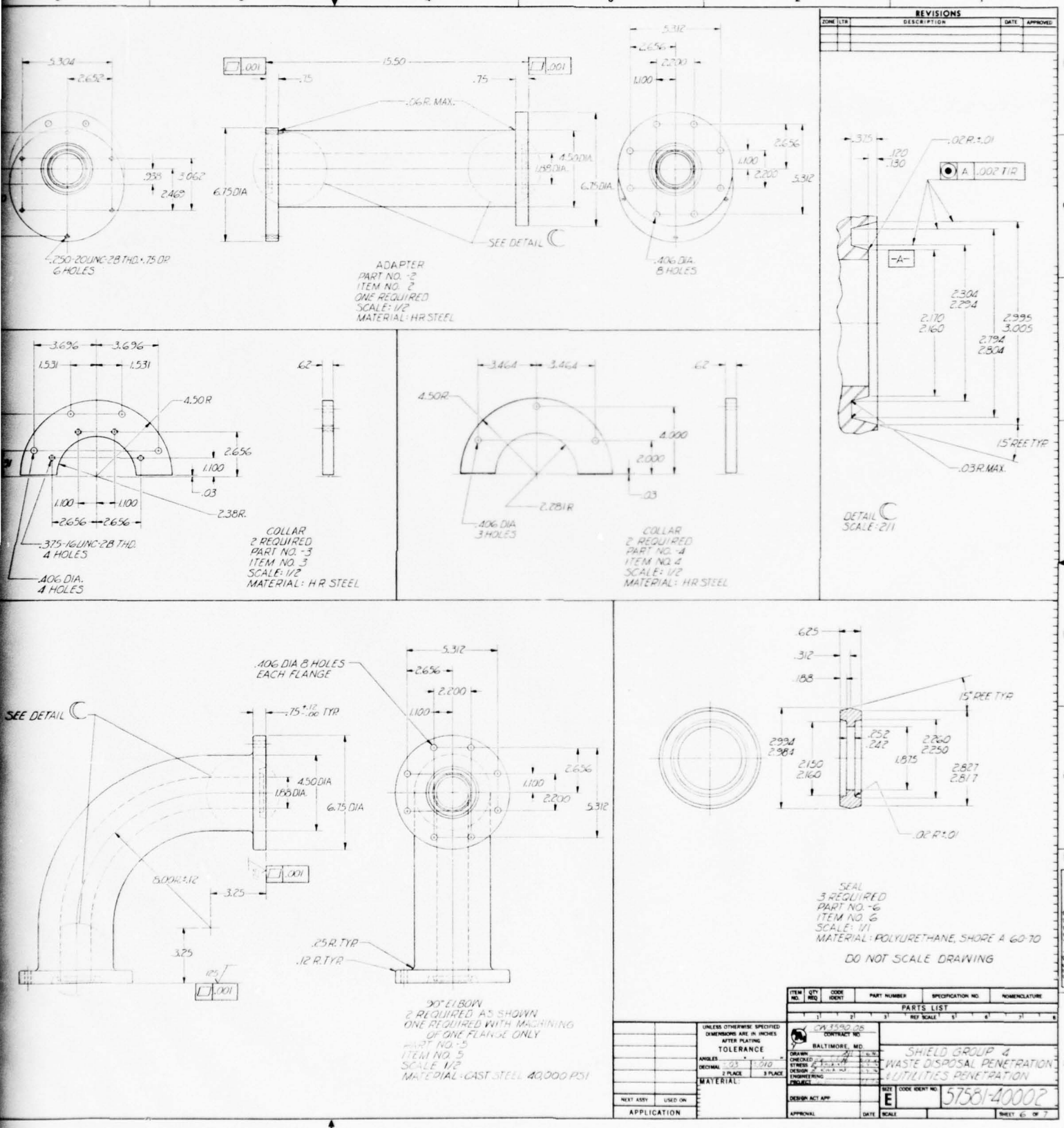

8
7
6
5
H
G
F
E
D
C
B
A
3.696
3.696
1.531
1.531
10.50
3.696
1.531
1.531
3.696
5.25
5.25
10.50
6.84 DIA.
.375-16 UNC-2B THD. x .75 DP.
8 HOLES
.75
10.75 +.12 -.00
.375-16 UNC-2B THD. x .75 DP.
6 HOLES
3.464
3.464
9.00
4.000
2.000
2.000
4.000
.75
.75
9.00
6.00 R
BUSHING
ONE REQUIRED
PART NO. -1
ITEM NO. 1
SCALE: 1/2
MATERIAL: H.R. STEEL
5.304
2.652
6.125
4.000
.938
3.062
2.468
.250-20 UNC-2B THD. x .75 DP.
6 HOLES
.001
.75
6.75 DIA
A
PART
ITEM
ONE
SCAL
MATE
3.696
3.696
1.531
1.531
4.50 R
3.696
1.531
2.656
1.100
.03
1.100
1.100
2.656
2.656
2.38 R.
.375-16 UNC-2B THD.
4 HOLES
.406 DIA.
4 HOLES
.62
COLLAR
2 REQUIRED
PART NO. -3
ITEM NO. 3
SCALE: 1/2
MATERIAL: H.R. STEEL
.406 DIA. 8 HOLES
EACH FLANGE
SEE DETAIL
.75 +.12 -.06 TYP.
4.50 DIA
1.65 DIA.
6.75 DIA
.001
6.00 R. ±.12
3.25
3.25
.25 R. TYP.
.12 R. TYP.
.125
.001



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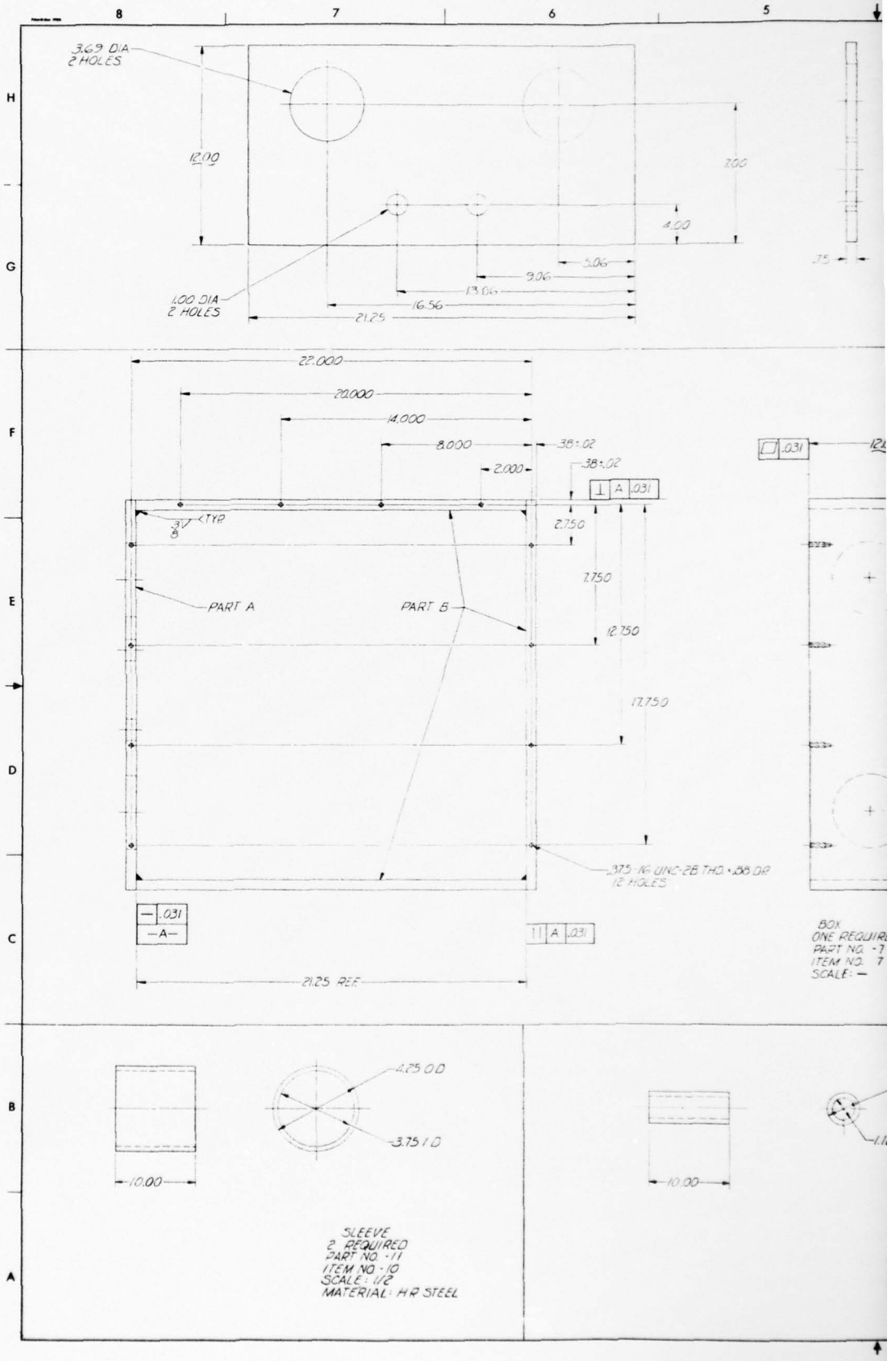
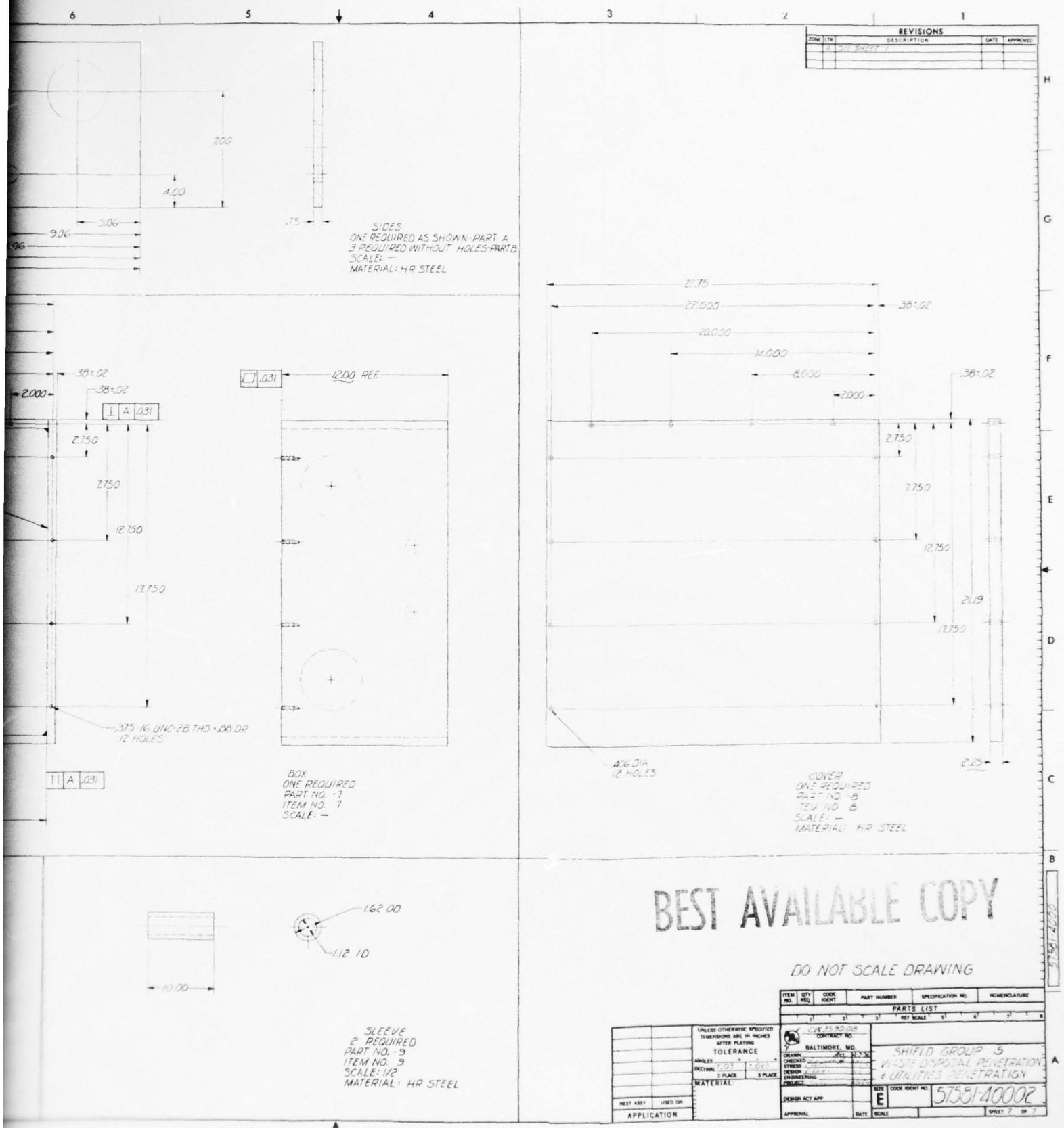
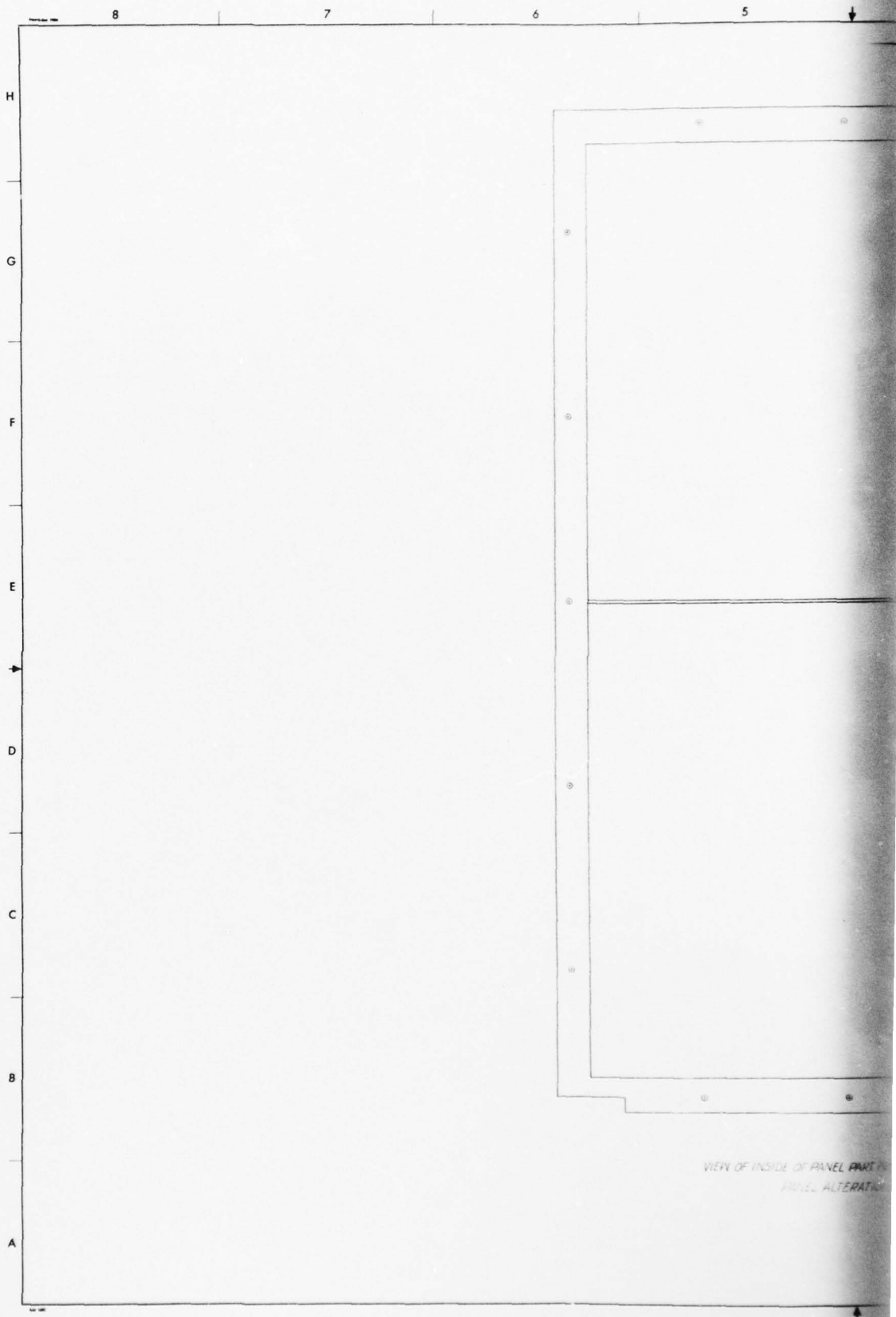

8
7
6
5
H
G
F
E
D
C
B
A
3.69 DIA
2 HOLES
12.00
7.00
4.00
1.00 DIA
2 HOLES
5.06
9.06
13.06
16.56
21.25
.75
22.000
20.000
14.000
8.000
2.000
.38±.02
.38±.02
⊥ A .031
.37
8 TYP
2.750
2.750
12.750
17.750
PART A
PART B
.375-16 UNC-2B THD × .88 DP
12 HOLES
— .031
—A—
// A .031
21.25 REF
□ .031
12
BOX
ONE REQUIR
PART NO. -7
ITEM NO. 7
SCALE: —
4.25 O.D
3.75 I.D
10.00
10.00
SLEEVE
2 REQUIRED
PART NO -11
ITEM NO -10
SCALE: 1/2
MATERIAL: H.R. STEEL


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
A SEE SHEET 1
7.00
4.00
5.06
9.06
.75
SIDES
ONE REQUIRED AS SHOWN-PART A
3 REQUIRED WITHOUT HOLES-PART B
SCALE: —
MATERIAL: HR STEEL
22.75
22.000
20.000
14.000
8.000
2.000
.38±.02
12.00 REF
.031
2.750
7.750
12.750
17.750
21.19
.375-16 UNC-2B THD. x .88 DP
12 HOLES
.406 DIA
12 HOLES
2.25
BOX
ONE REQUIRED
PART NO. -7
ITEM NO. 7
SCALE: —
COVER
ONE REQUIRED
PART NO. -8
ITEM NO. 8
SCALE: —
MATERIAL: HR STEEL
1.62 OD
1.12 ID
10.00
SLEEVE
2 REQUIRED
PART NO. -9
ITEM NO. 9
SCALE: 1/2
MATERIAL: HR STEEL
BEST AVAILABLE COPY
DO NOT SCALE DRAWING
ITEM NO. QTY REQ CODE IDENT PART NUMBER SPECIFICATION NO. NOMENCLATURE
PARTS LIST
REF SCALE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES
DECIMAL ±.03 ±.010
2 PLACE 3 PLACE
MATERIAL:
NEXT ASSY USED ON
APPLICATION
CW3590.08
CONTRACT NO.
BALTIMORE, MD.
DRAWN
CHECKED
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL DATE
SHIELD GROUP 5
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION
SIZE E CODE IDENT NO. 57581-40002
SCALE SHEET 7 OF 7
57581-4000


8
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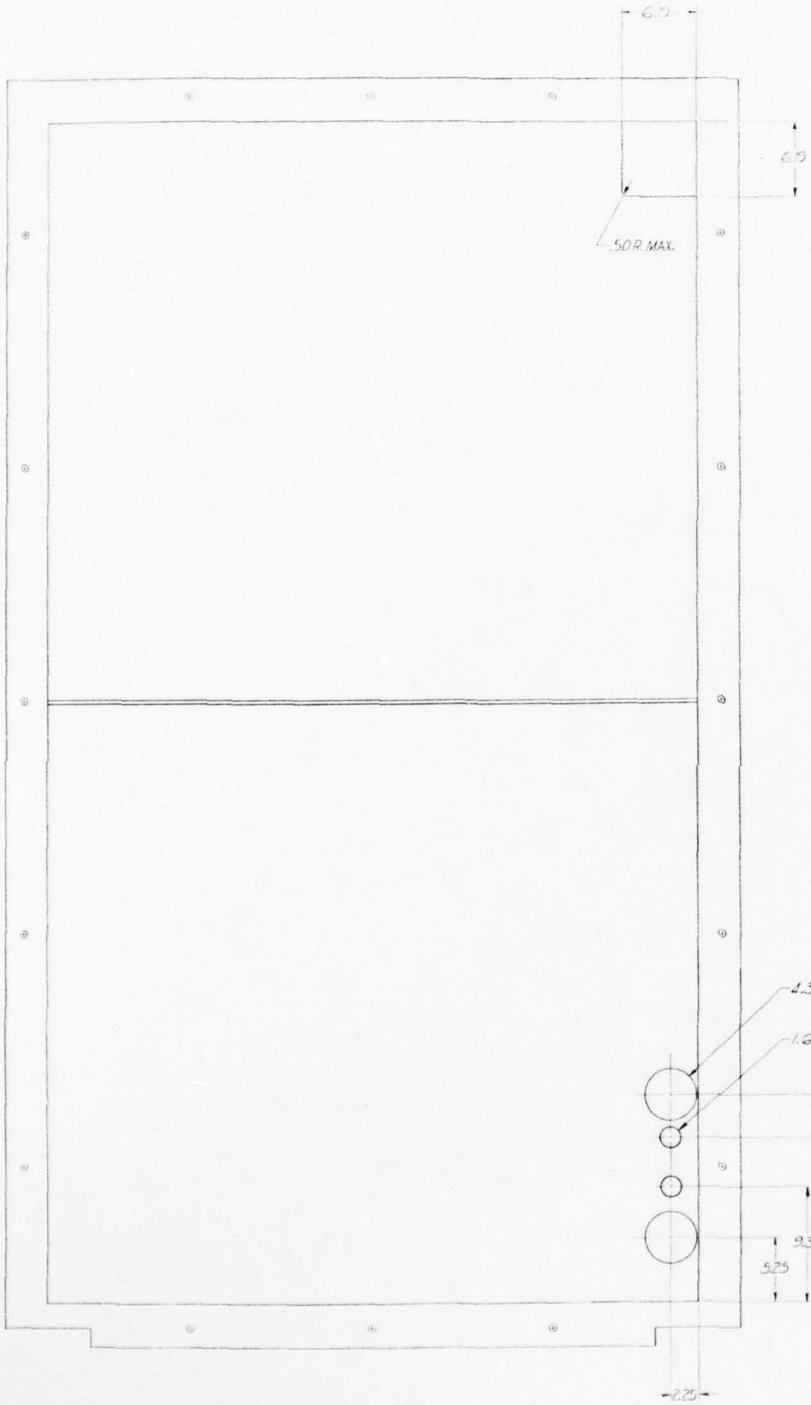
A

BEST AVAILABLE COPY

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	[illegible]	[illegible]	[illegible]



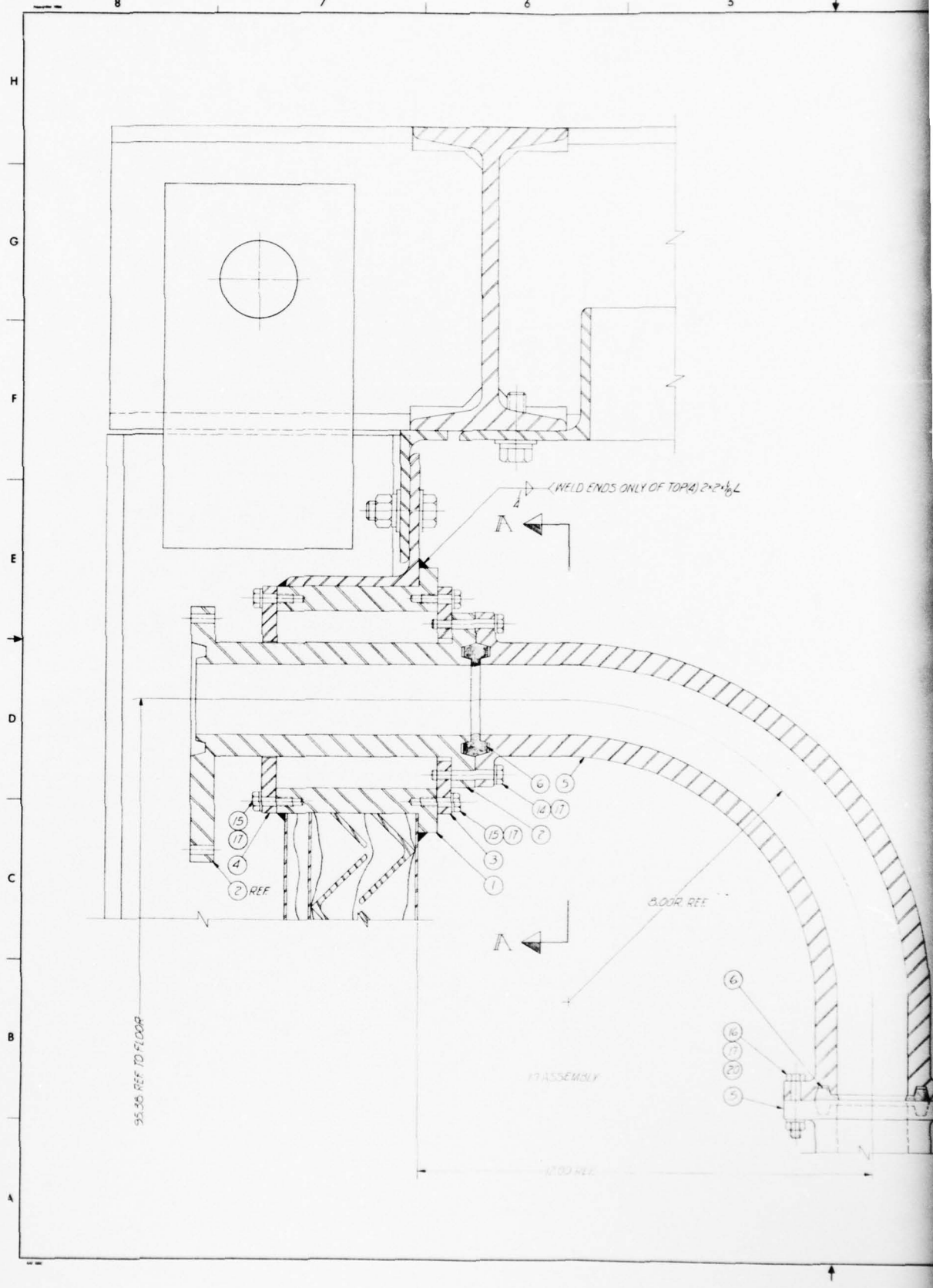
VIEW OF INSIDE OF PANEL PART NO. 1E700F33011-2
PANEL ALTERATIONS

DO NOT SCALE DRAWING

ITEM NO	QTY REQ	QTY PER	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
15	12			MS51971-3	1/4 DIA	NUT, HEX
14	12	34		MS35336-139	1/4 DIA	WASHER, LOCK
13	12	12		MS51854-12	1/4 DIA - .62 LG	SCREW, CAP, HEX
12	10	10		MS90726-10	1/4 DIA - .88 LG	SCREW, CAP, HEX
11	6	6		MS90726-13	1/4 DIA - 1.25 LG	SCREW, CAPHEX
10	2					SLEEVE
9	2					SLEEVE
8	1					COVER
7	1					BOX
6	3					SEAL
5	3					90° ELBOW
4	2					COLLAR
3	2					COLLAR
2	2					ADAPTER
1	1					BUSHING
						UTILITIES PEN
						WASTE DISP PEN

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING TOLERANCE: ANGLES ± °, DECIMAL .X ± .1, .XX ± .01, 2 PLACE, 3 PLACE	GENERAL DYNAMICS CONTRACT NO. BALTIMORE, MD.	SHIELD GROUP 3 WASTE DISPOSAL PENETRATION & UTILITIES PENETRATION	
MATERIAL	DRAWN, CHECKED, STRESS, DESIGN, ENGINEERING, PROJECT	SIZE E	CODE IDENT NO. 57581-40003
NEXT ASSY / USED ON: APPLICATION	DESIGN ACT APP: APPROVAL / DATE	SCALE 1/2	SHEET 1 OF 5



8
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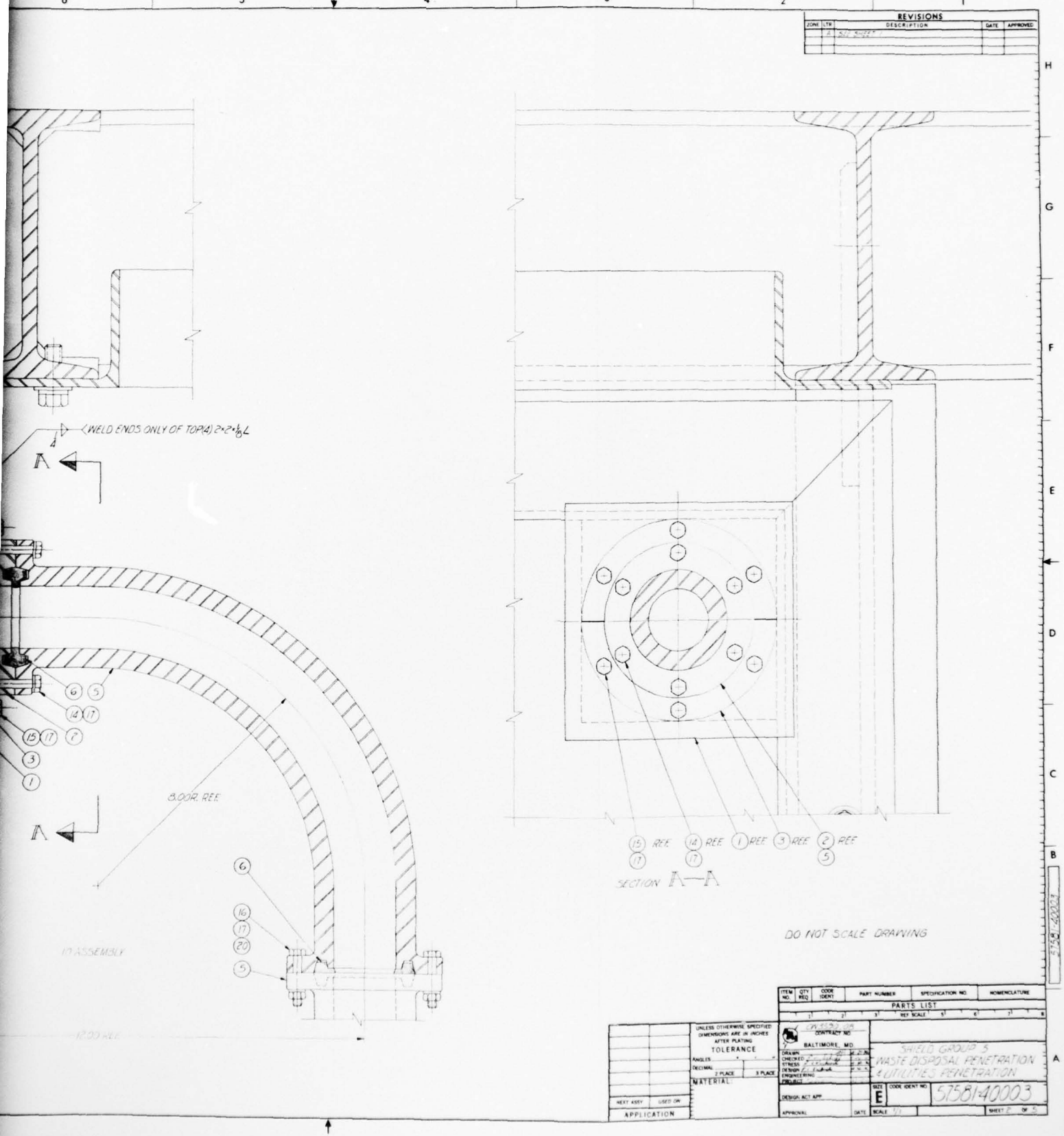
B
A
WELD ENDS ONLY OF TOP(4) 2×2×1/8 L
6
5
14
17
15
17
2
3
1
15
17
4
2 REF
8.00R REF
95.38 REF TO FLOOR
6
16
17
20
5



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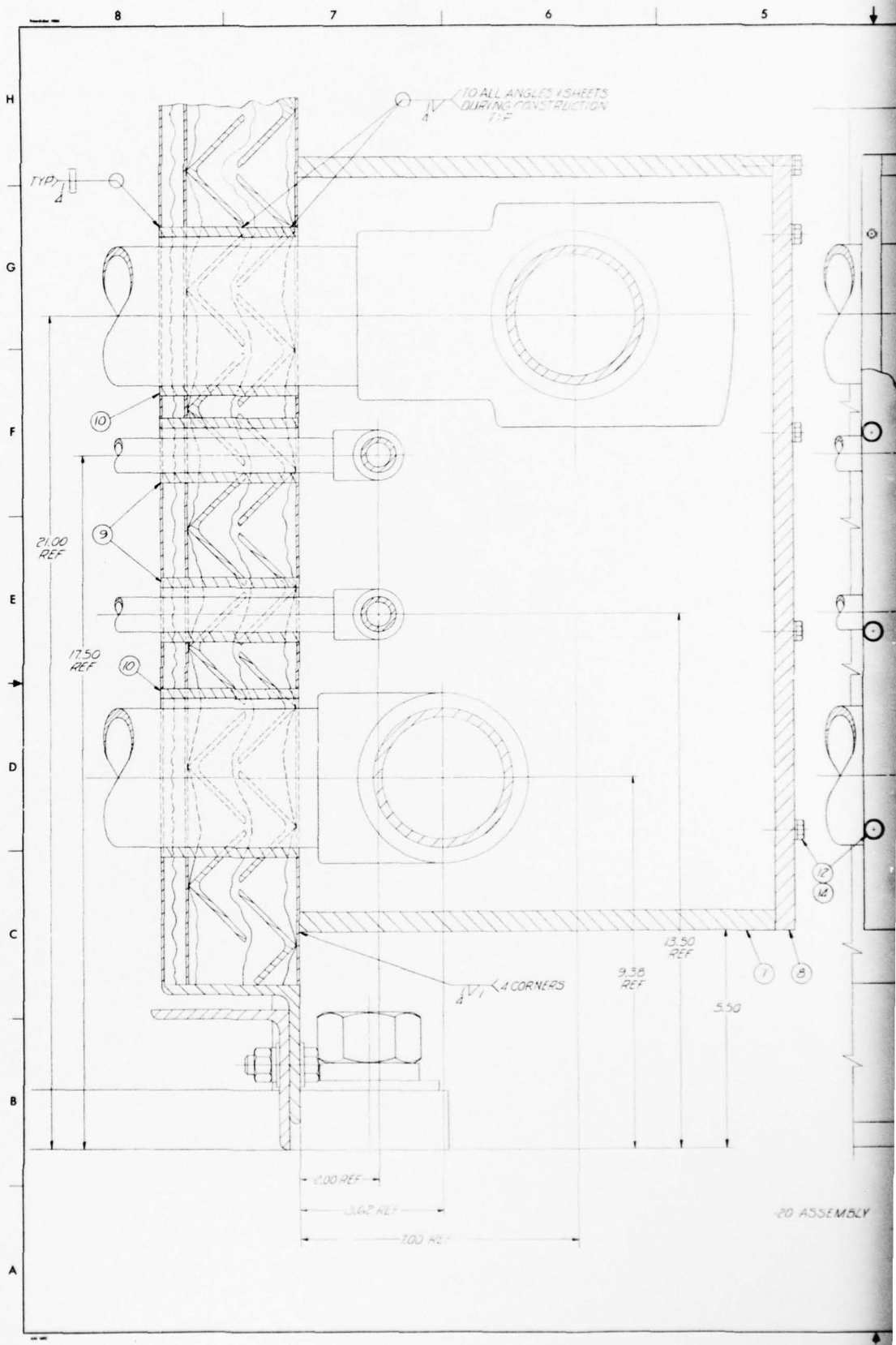
8
7
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H
G
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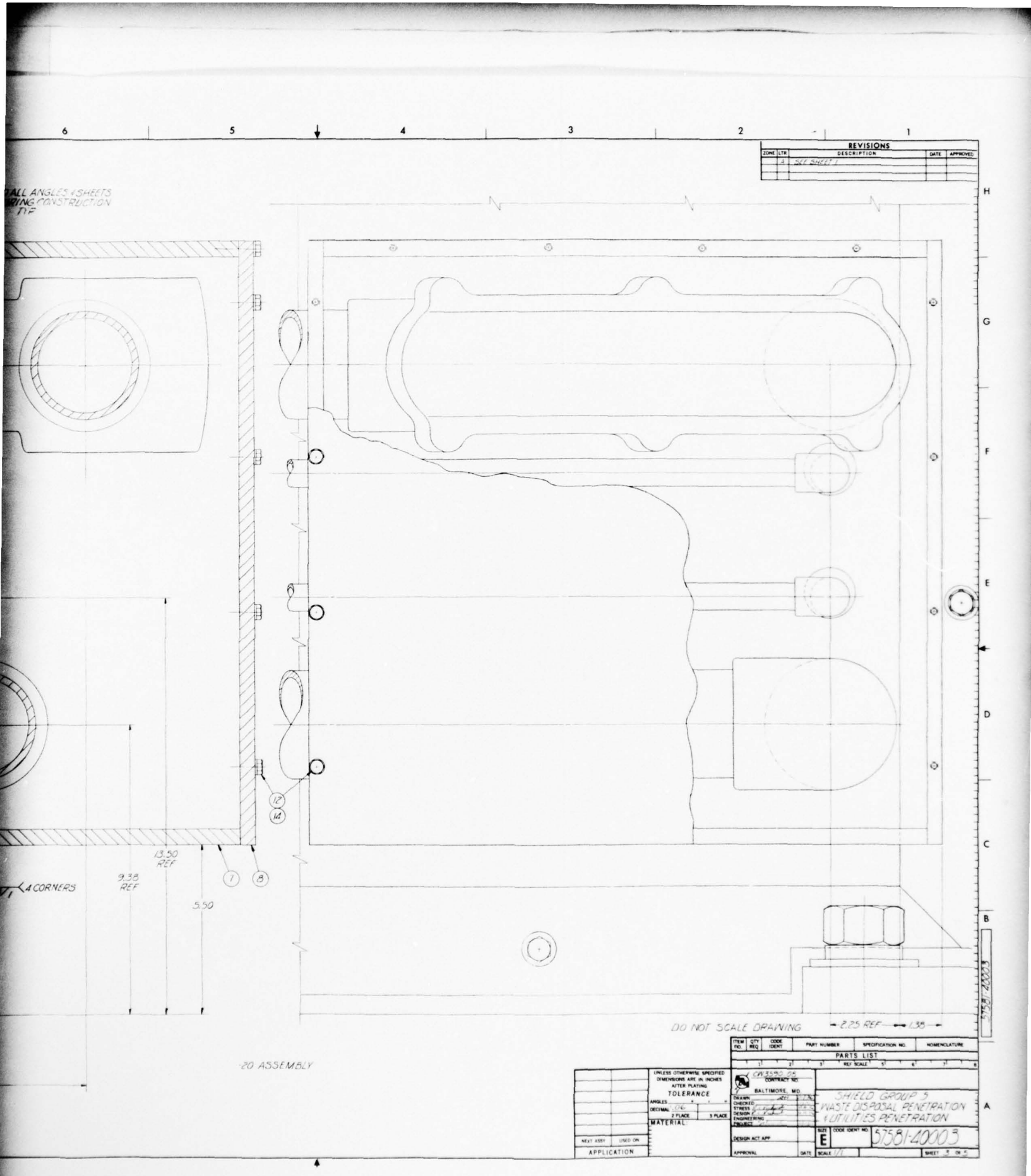
E
D
C
B
A
TYP
4
TO ALL ANGLES & SHEETS
DURING CONSTRUCTION
TYP
4
10
9
10
21.00
REF
17.50
REF
4
4 CORNERS
13.50
REF
9.38
REF
5.50
12
14
7
8
2.00 REF
3.62 REF
7.00 REF
20 ASSEMBLY



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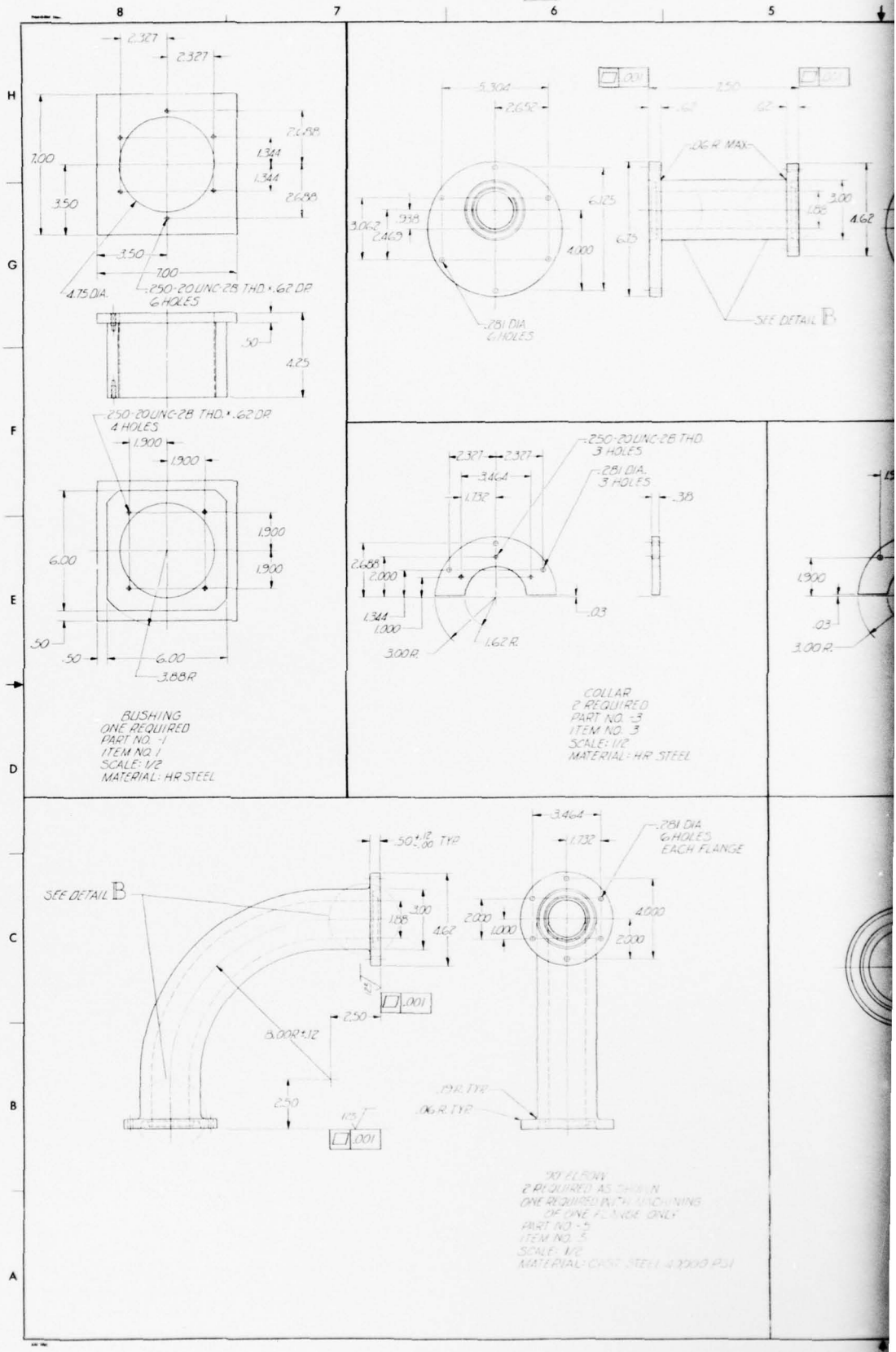
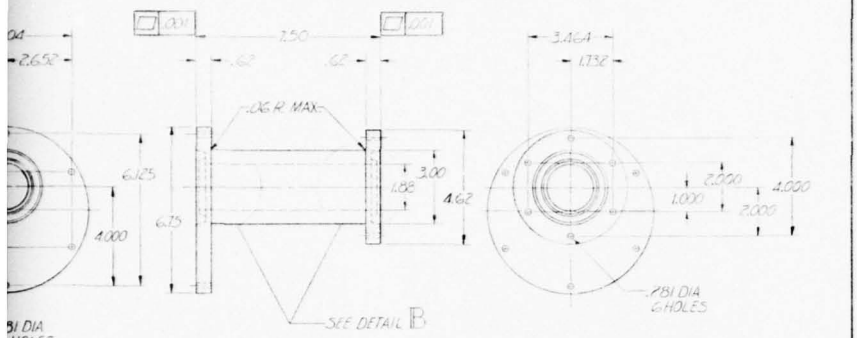
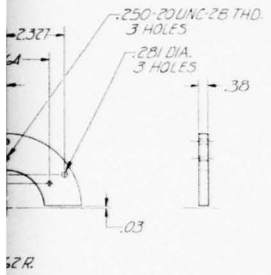


BUSHING
ONE REQUIRED
PART NO. -1
ITEM NO. 1
SCALE: 1/2
MATERIAL: HR STEEL
4.75 DIA.
.250-20 UNC-2B THD. × .62 DP.
6 HOLES
.250-20 UNC-2B THD. × .62 DP.
4 HOLES
3.88 R
.281 DIA
6 HOLES
.06 R MAX.
SEE DETAIL B
COLLAR
2 REQUIRED
PART NO. -3
ITEM NO. 3
SCALE: 1/2
MATERIAL: HR STEEL
.250-20 UNC-2B THD.
3 HOLES
.281 DIA.
3 HOLES
3.00 R.
1.62 R.
SEE DETAIL B
.281 DIA
6 HOLES
EACH FLANGE
8.00 R ± .12
.19 R. TYP.
.06 R. TYP.
90° ELBOW
2 REQUIRED AS SHOWN
ONE REQUIRED WITH MACHINING
OF ONE FLANGE ONLY
PART NO. -5
ITEM NO. 5
SCALE: 1/2
MATERIAL: CAST STEEL 40,000 PSI

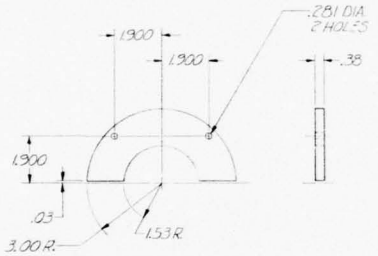
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
		SEE SHEET		



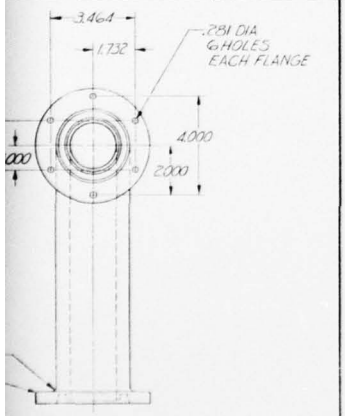
ADAPTER
ONE REQUIRED
PART NO. -2
ITEM NO. 2
SCALE: 1/2
MATERIAL: H.R. STEEL



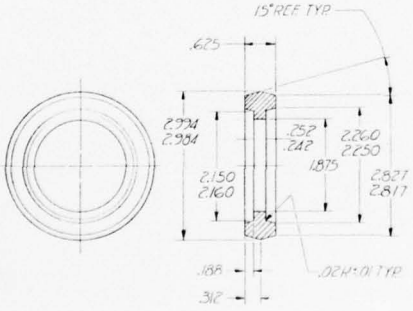
COLLAR
2 REQUIRED
PART NO. -3
ITEM NO. 3
SCALE: 1/2
MATERIAL: H.R. STEEL



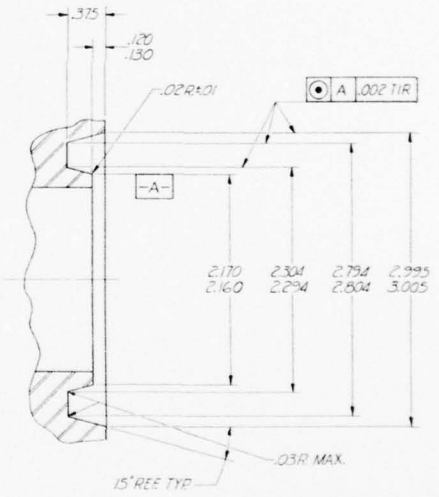
COLLAR
2 REQUIRED
PART NO. -4
ITEM NO. 4
SCALE: 1/2
MATERIAL: H.R. STEEL



90° ELBOW
2 REQUIRED AS SHOWN
ONE REQUIRED WITH MACHINING
OF ONE FLANGE ONLY
PART NO. -5
ITEM NO. 5
SCALE: 1/2
MATERIAL: CAST STEEL 40000 PSI



SEAL
3 REQUIRED
PART NO. -6
ITEM NO. 6
SCALE: 1/1
MATERIAL: POLYURETHANE, SHORE A 60 TO



DETAIL B
SCALE: 2/1

DO NOT SCALE DRAWING

BEST AVAILABLE COPY

ITEM NO.	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
PARTS LIST					

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES ± DECIMAL .X ± .010 2 PLACE ± .005 3 PLACE
MATERIAL:
NEXT ASSY | USED ON
APPLICATION

CONTRACT NO.
BALTIMORE, MD.
DRAWN
CHECKED
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP.
APPROVAL DATE

SHIELD GROUP 5
WASTE DISPOSAL PENETRATION
& UTILITIES PENETRATION

SIZE E | CODE IDENT NO. | 57581-40003
SCALE | SHEET 2 OF 3

57581-40003

179

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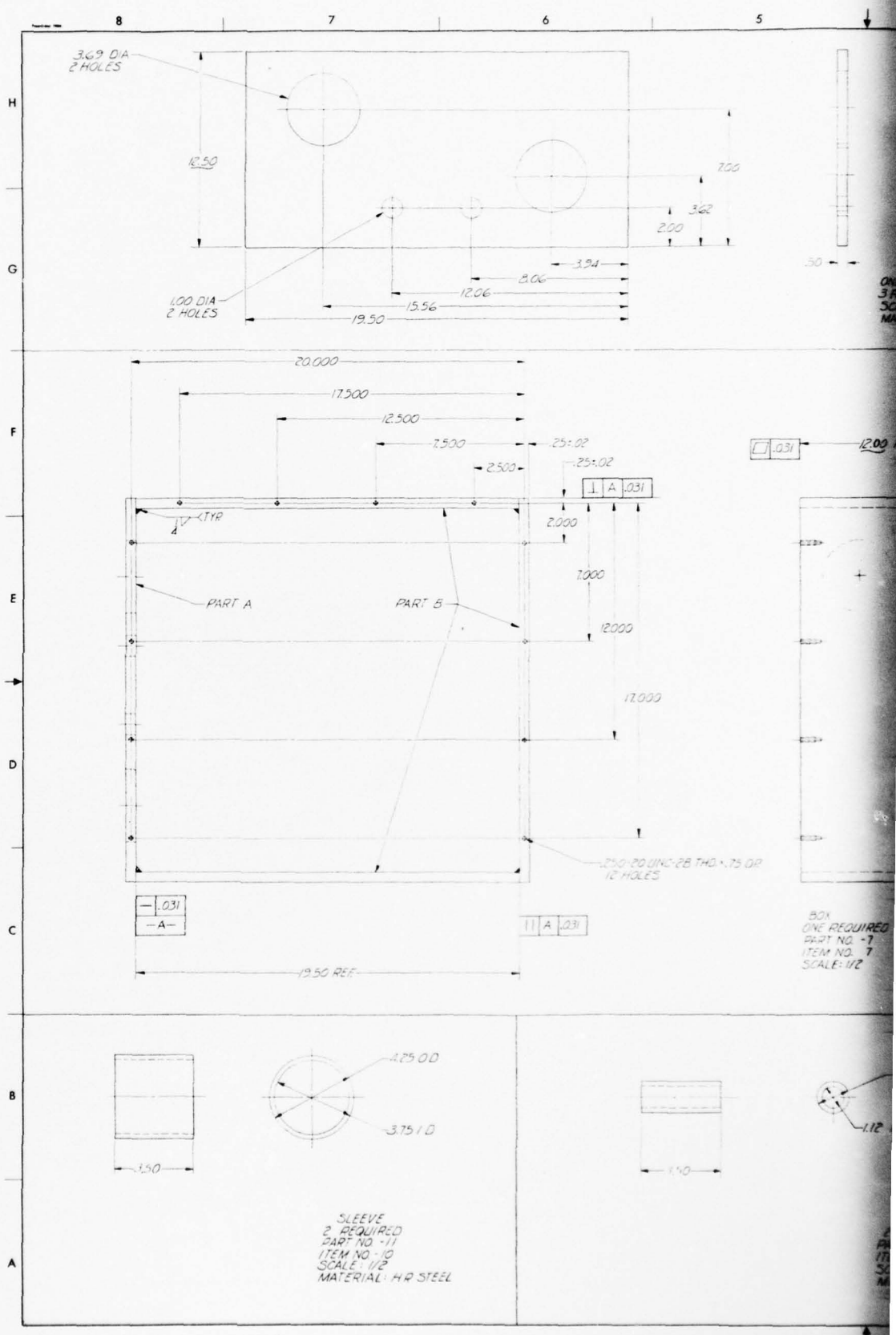
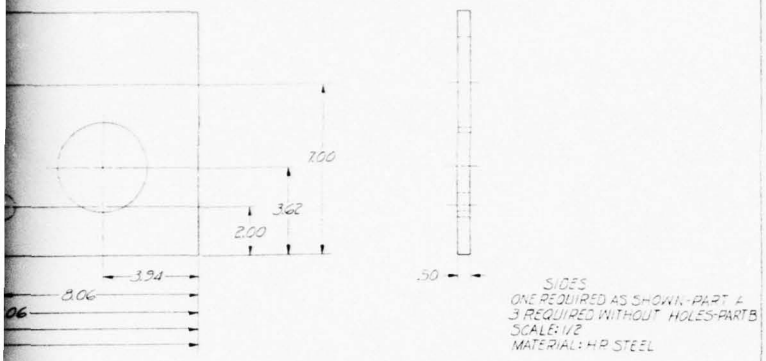
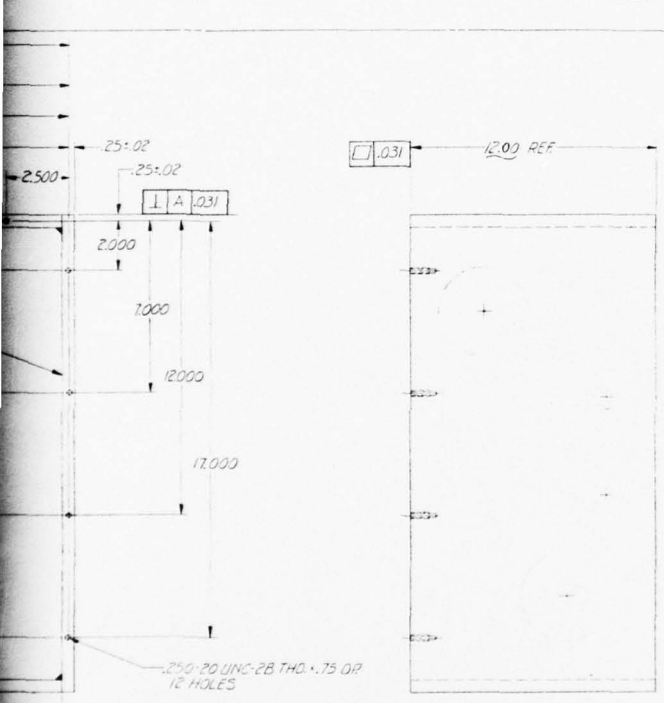


3.69 DIA
2 HOLES
12.50
7.00
3.62
2.00
3.94
8.06
12.06
15.56
19.50
1.00 DIA
2 HOLES
.50
20.000
17.500
12.500
7.500
2.500
.25±.02
.25±.02
.031
12.00
TYP
2.000
7.000
12.000
17.000
PART A
PART B
.250-20 UNC-2B THD. x .75 DP
12 HOLES
.031
A
19.50 REF.
BOX
ONE REQUIRED
PART NO. -7
ITEM NO. 7
SCALE: 1/2
4.25 O.D.
3.75 I.D.
3.50
1.50
1.12
SLEEVE
2 REQUIRED
PART NO. -11
ITEM NO. -10
SCALE: 1/2
MATERIAL: H.R. STEEL

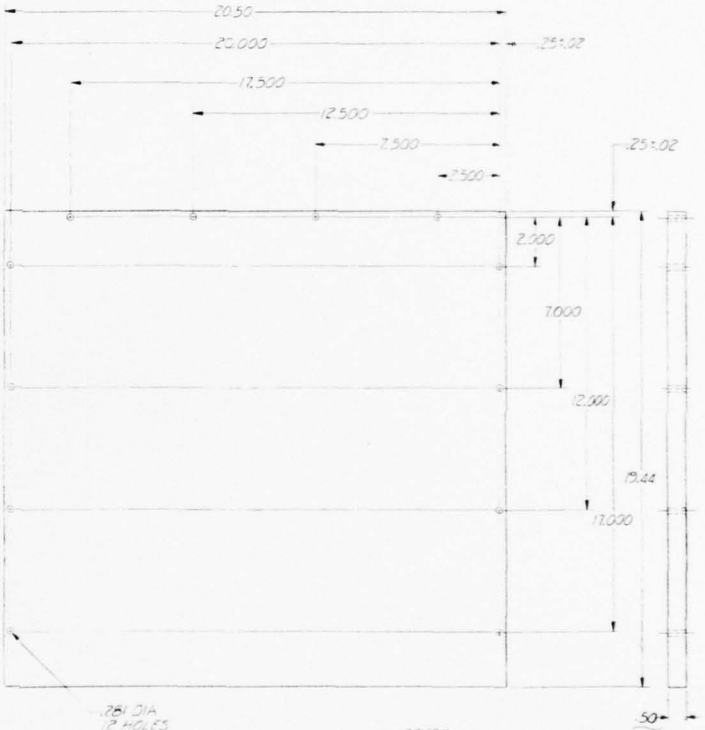
REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADD SHEET 5		



SIDES
ONE REQUIRED AS SHOWN - PART A
3 REQUIRED WITHOUT HOLES - PART B
SCALE: 1/2
MATERIAL: HR STEEL



BOX
ONE REQUIRED
PART NO. -7
ITEM NO. 7
SCALE: 1/2



COVER
ONE REQUIRED
PART NO. -8
ITEM NO. 8
SCALE: 1/2
MATERIAL: HR STEEL

SLEEVE
2 REQUIRED
PART NO. -9
ITEM NO. 9
SCALE: 1/2
MATERIAL: HR STEEL

BEST AVAILABLE COPY

DO NOT SCALE DRAWING

ITEM NO.	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE

PARTS LIST

REF SCALE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING	CONTRACT NO. DAAK11-90-D-0008	SHIELD GROUP 5 WASTE DISPOSAL PENETRATION & UTILITIES PENETRATION
TOLERANCE	BALTIMORE, MD.	
ANGLES ° ' "	DRAWN	
DECIMAL .XX 2 PLACE .X 1 PLACE	CHECKED	
MATERIAL	STRESS	
	DESIGN	
	ENGINEERING	
	PROJECT	
NEXT ASSY / USED ON	DESIGN ACT APP	SIZE E / CODE IDENT NO. / 57581-40003
APPLICATION	APPROVAL / DATE	SCALE / SHEET 5 OF 5

181

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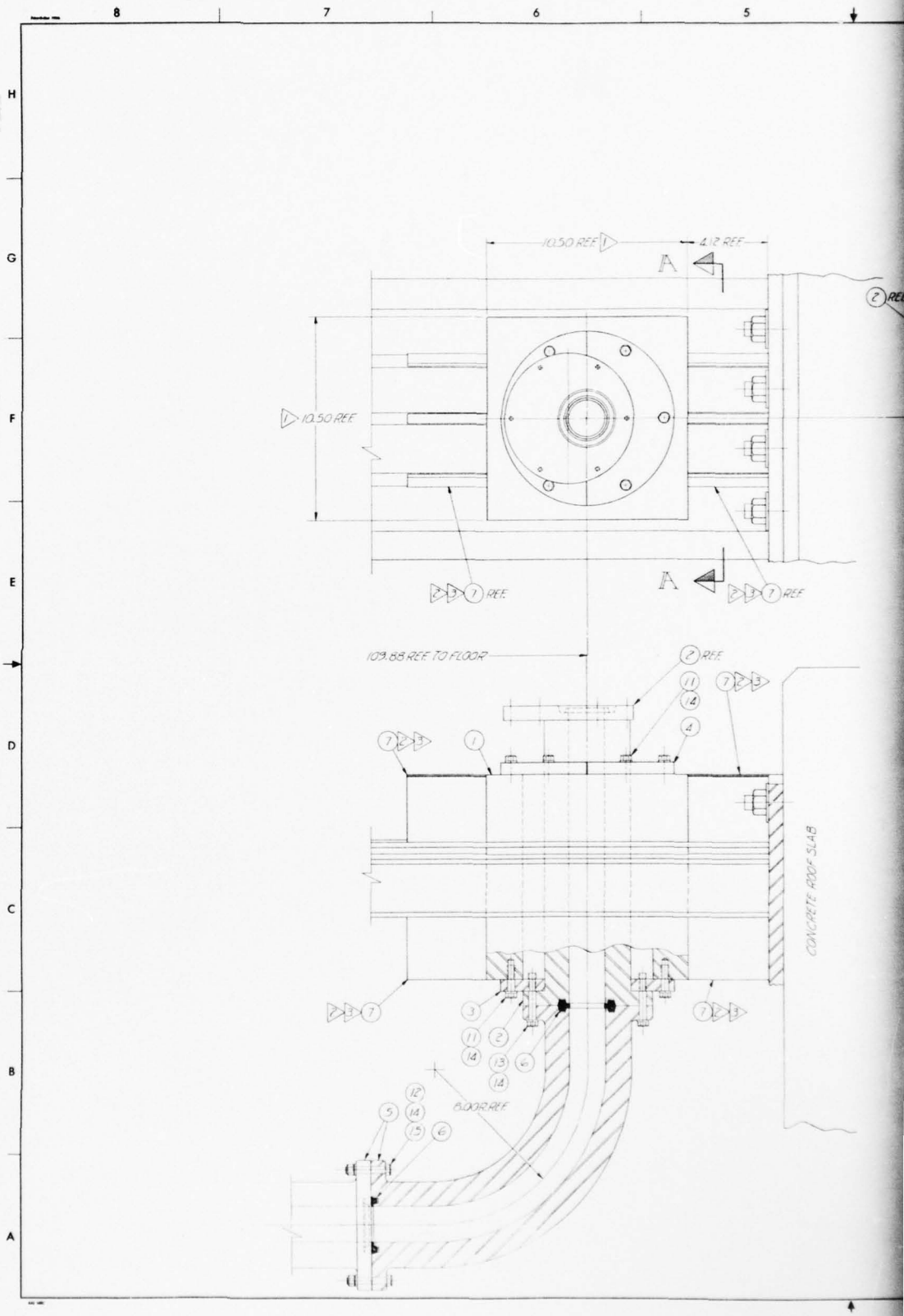
2


8
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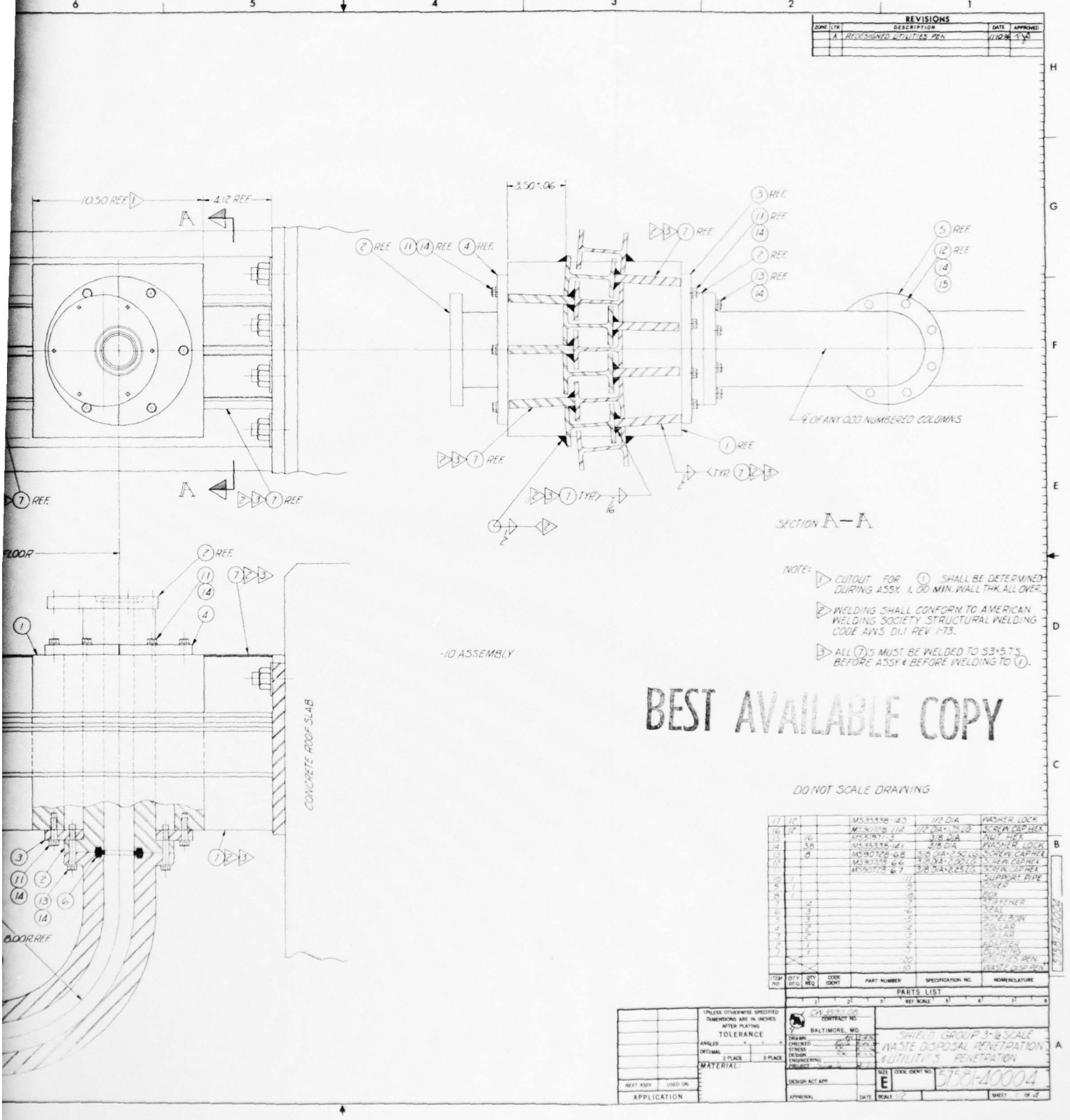
C
B
A
10.50 REF
4.12 REF
A
10.50 REF
7 REF
7 REF
109.88 REF TO FLOOR
2 REF
11
14
4
1
CONCRETE ROOF SLAB
3
11
14
2
13
6
14
12
14
5
15
6
FLOOR REF



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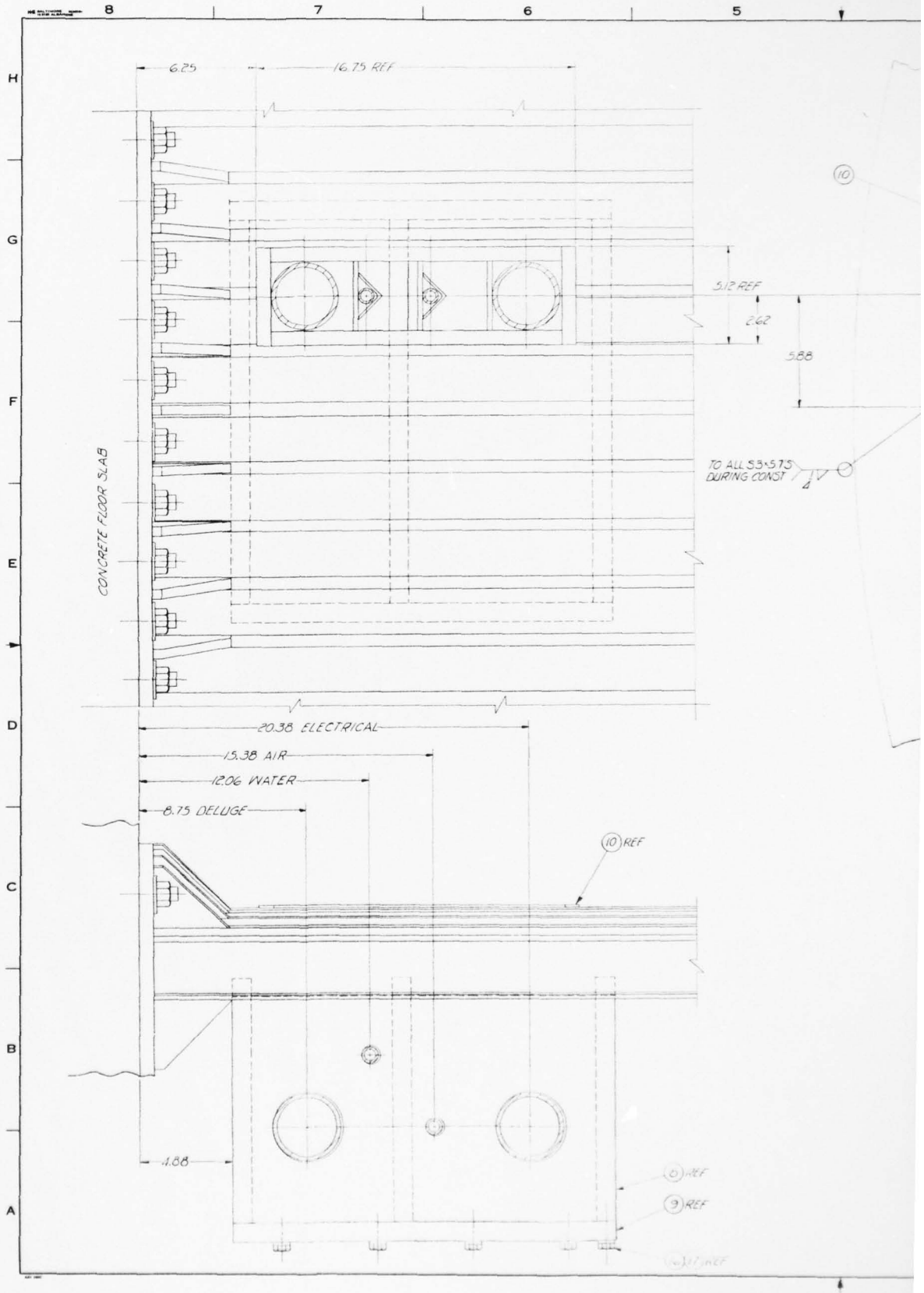


8
7
6
5
H
G
F
E
D
C
B
A
6.25
16.75 REF
5.12 REF
2.62
5.88
CONCRETE FLOOR SLAB
TO ALL S3×5.7S DURING CONST
20.38 ELECTRICAL
15.38 AIR
12.06 WATER
8.75 DELUGE
10 REF
4.88
9 REF

AD-A037 414 AAI CORP BALTIMORE MD F/G 13/13

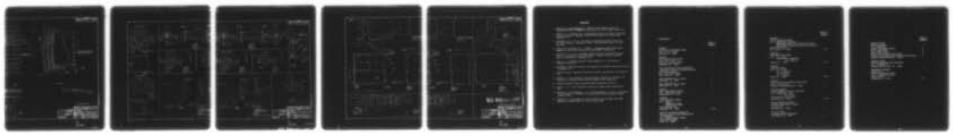
ENGINEERING DESIGN GUIDELINES, DRAWINGS AND SPECIFICATIONS FOR --ETC(U)

DEC 76 F J SCHROEDER, R L KACHINSKI DAAA15-75-C-0120

UNCLASSIFIED AAI-ER-8723-A EM-CR-76097 NL

3 OF 3

AD A037414



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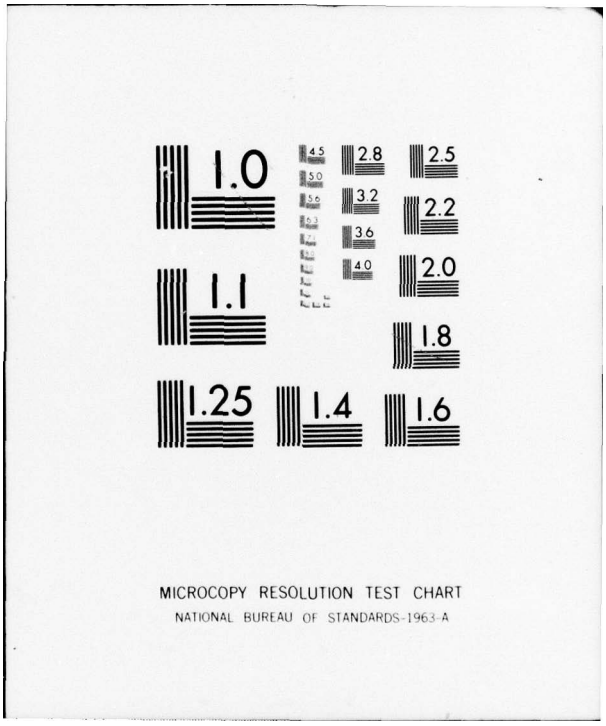
DATE FILMED

5-77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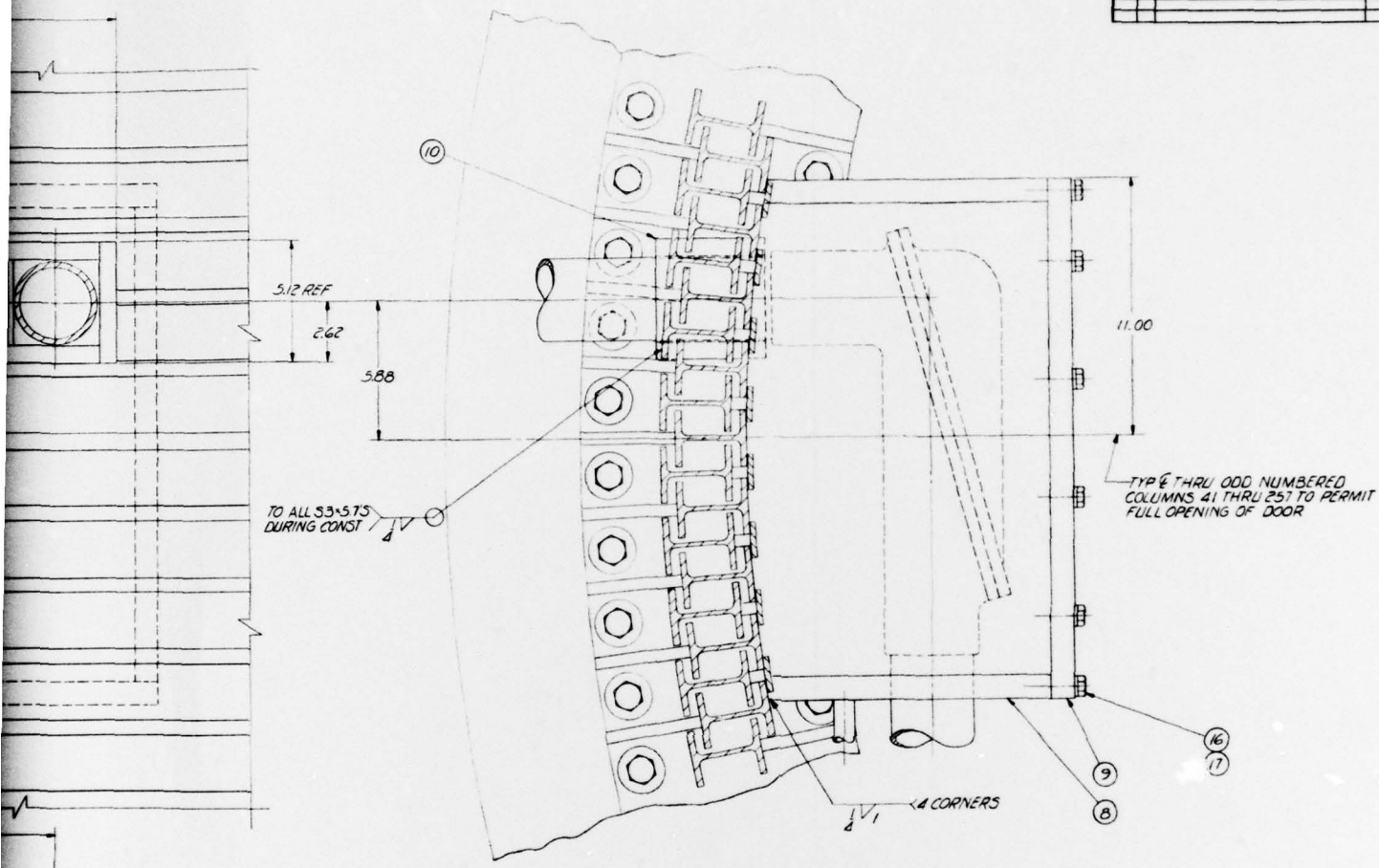
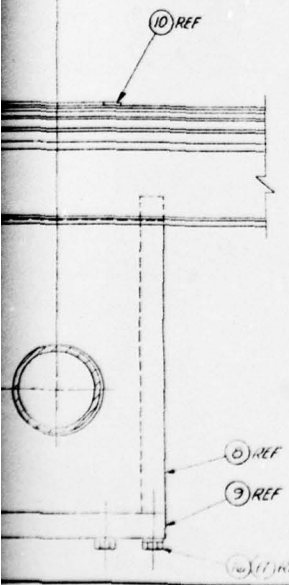
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE SHEET 1		



-20 ASSEMBLY



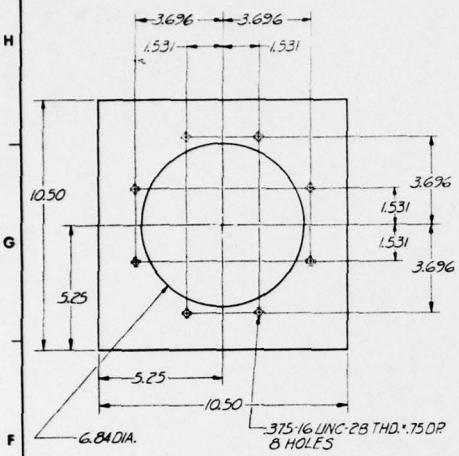
BEST AVAILABLE COPY

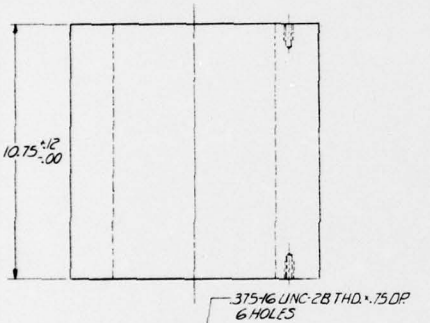
DO NOT SCALE DRAWING

ITEM NO.	QTY REQ.	CODE IDENT	PART NUMBER	SPECIFICATION NO.	NOMENCLATURE
PARTS LIST					

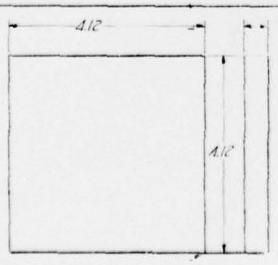
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING TOLERANCE ANGLES ± ′ ″ DECIMAL .X ± .05 2 PLACE .XX ± .01 3 PLACE MATERIAL:	CONTRACT NO. CW-3550.08 BALTIMORE, MD.		
NEXT ASSY | USED ON APPLICATION	DRAWN JH 10-7-85 CHECKED STRESS DESIGN ENGINEERING PROJECT DESIGN ACT APP APPROVAL DATE	SHIELD GROUP 3 - ½ SCALE WASTE DISPOSAL PENETRATION & UTILITIES PENETRATION	SIZE E | CODE IDENT NO. 57581-40004 | SCALE 1/2 | SHEET 2 OF 4

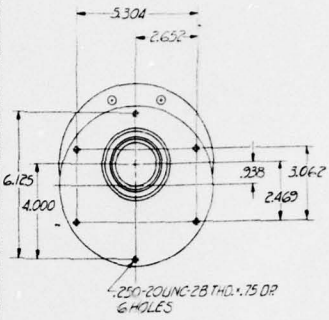
57581-40004

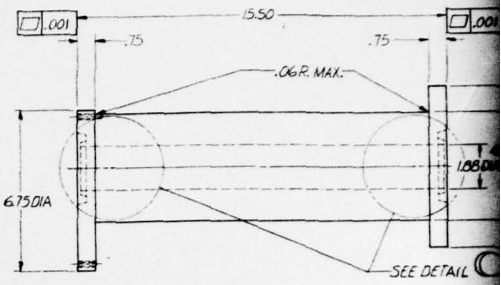




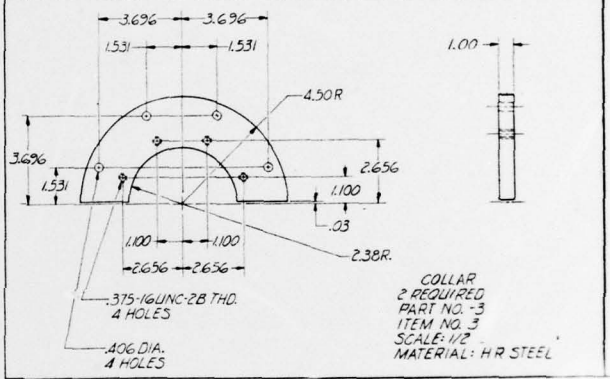
BUSHING
ONE REQUIRED
PART NO. -1
ITEM NO. 1
SCALE: 1/2
MATERIAL: HR STEEL



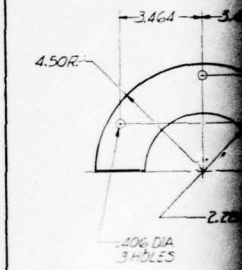


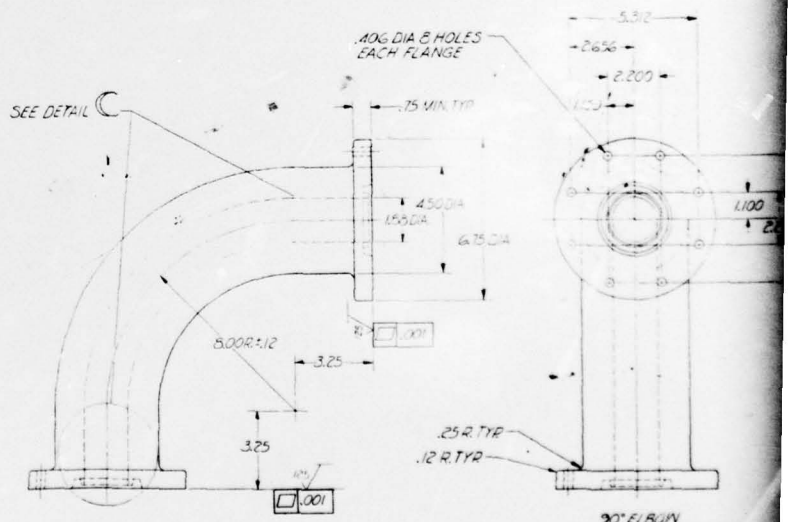


ADAPTER
PART NO. -2
ITEM NO. 2
ONE REQUIRED
SCALE: 1/2
MATERIAL: HR STEEL

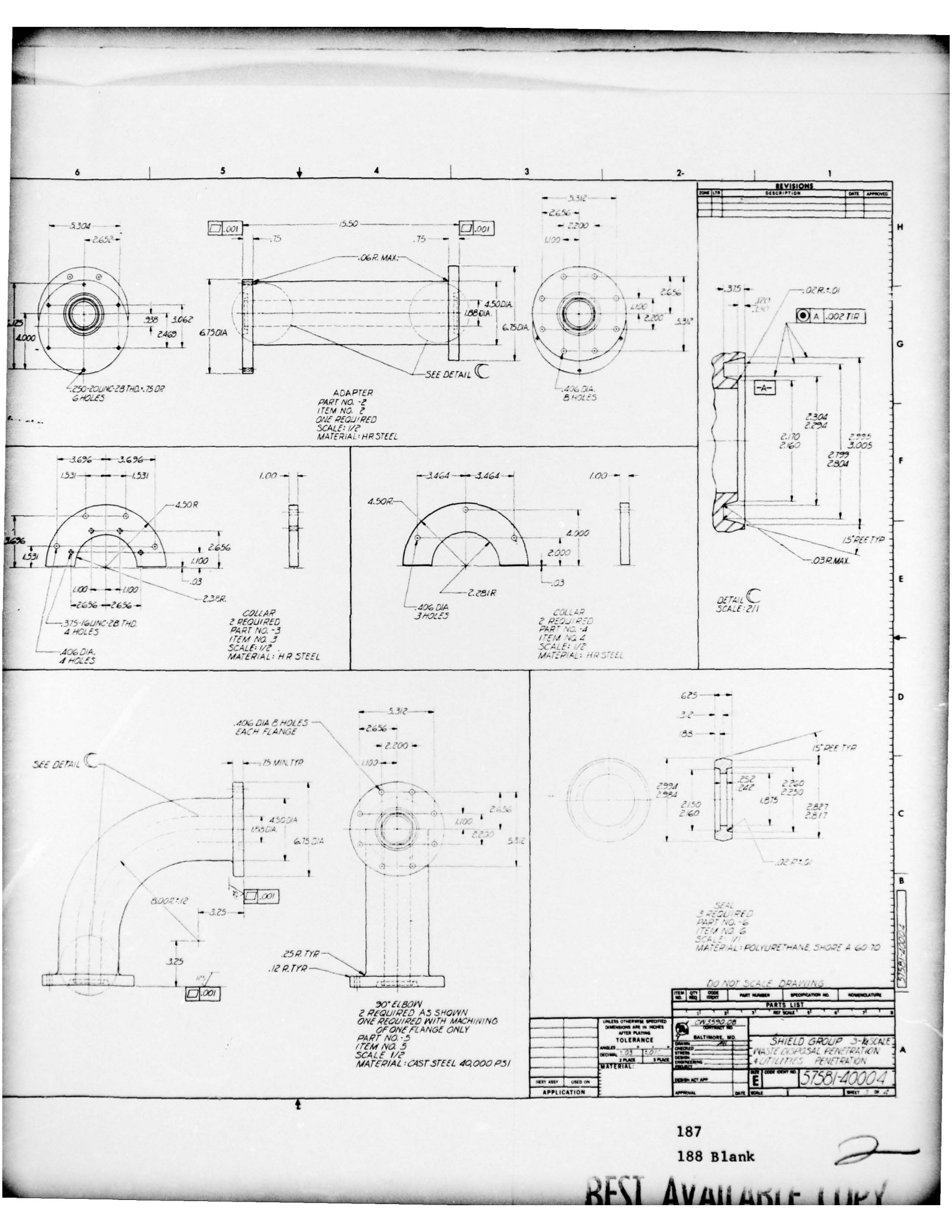


COLLAR
2 REQUIRED
PART NO. -3
ITEM NO. 3
SCALE: 1/2
MATERIAL: HR STEEL

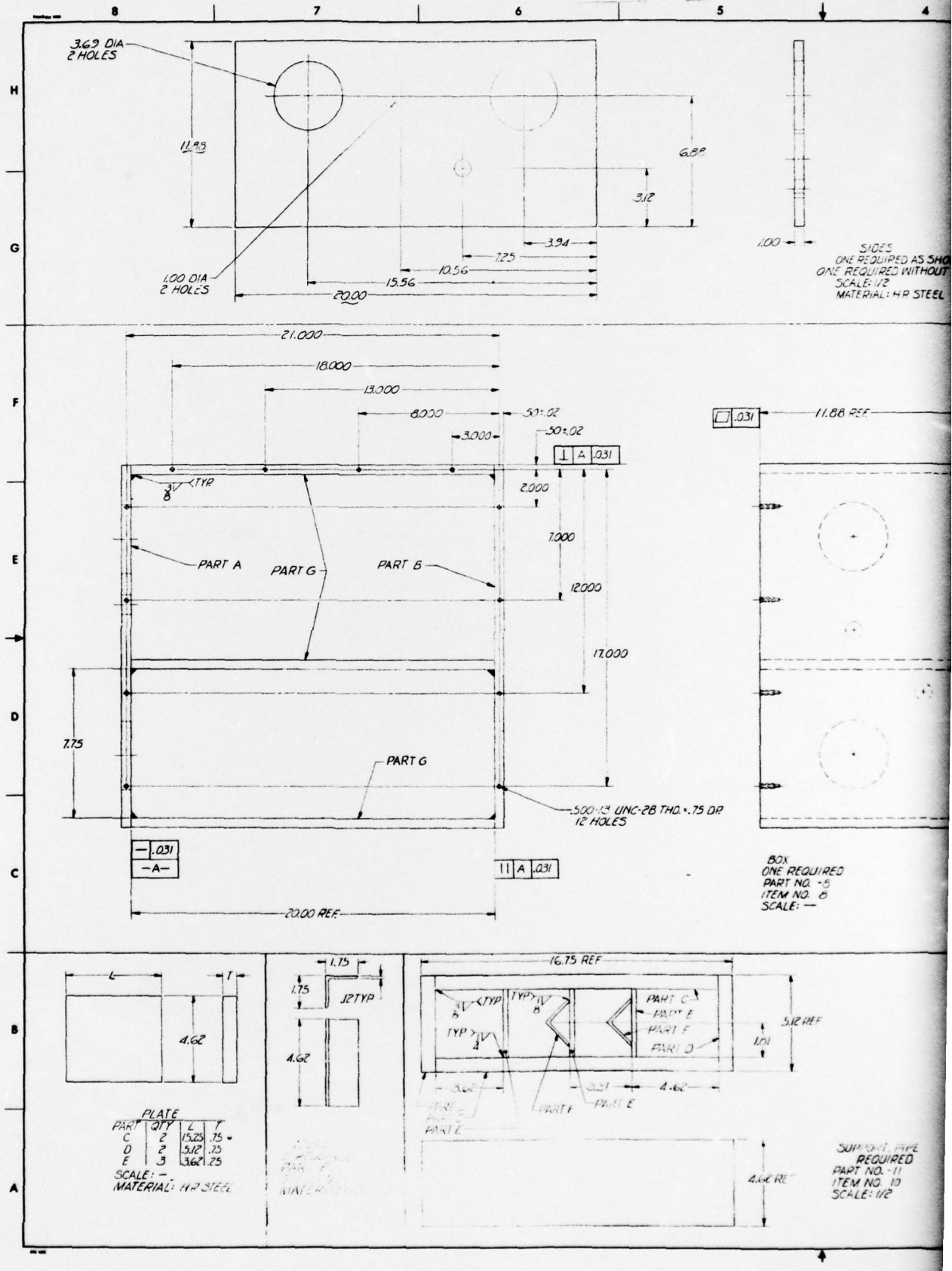




30° ELBOW
2 REQUIRED AS SHOWN
ONE REQUIRED WITH MACHINED
OF ONE FLANGE ONLY
PART NO. -5
ITEM NO. 5
SCALE 1/2
MATERIAL: CAST STEEL



BEST AVAILABLE COPY


8
7
6
5
4
H
G
F
E
D
C
B
A
3.69 DIA
2 HOLES
11.93
6.88
3.12
1.00 DIA
2 HOLES
3.94
7.25
10.56
13.56
20.00
1.00
SIDES
ONE REQUIRED AS SHO
ONE REQUIRED WITHOUT
SCALE: 1/2
MATERIAL: H.P. STEEL
21.000
18.000
13.000
8.000
3.000
.50±.02
.50±.02
⊥ A .031
.31 TYP
2.000
7.000
12.000
17.000
PART A
PART G
PART B
7.75
PART G
.500-13 UNC-2B THD. x .75 DP
12 HOLES
— .031
— A —
11 A .031
20.00 REF
□ .031
11.88 REF
BOX
ONE REQUIRED
PART NO. -5
ITEM NO. 6
SCALE: —
L
T
4.62
PLATE
PART | QTY | L | T
C | 2 | 15.25 | .75
D | 2 | 5.12 | .25
E | 3 | 3.62 | .25
SCALE: —
MATERIAL: H.P. STEEL
1.75
1.75
12 TYP
4.62
16.75 REF
TYP
PART C
PART E
PART F
PART D
5.12 REF
1.01
3.62
.31
4.62
PART F
PART E
PART E
PART C
4.00 REF
SUPPORT, PIPE
REQUIRED
PART NO. -11
ITEM NO. 10
SCALE: 1/2

189

190 Blank

2

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